JOURNAL

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OF THE INSTITUTION OF ELECTRICAL ENGINEERS

SAVOY PLACE LONDON W.C.2

TELEPHONE: TEMPLE BAR 7676 TELEGRAMS: VOLTAMPERE PHONE LONDON

VOLUME 1 (NEW SERIES) NUMBER 9 SEPTEMBER 1955

PUBLISHED MONTHLY PRICE FIVE SHILLINGS

ANNUAL SUBSCRIPTION TWENTY-FIVE SHILLINGS

Contents

PAGE	
551	THE PROFESSIONAL ENGINEER AS ADMINISTRATOR
552	THE INTERNATIONAL ELECTROTECHNICAL COMMISSION
553	THE FIRST GRAHAM CLARK LECTURE *by* SIR HAROLD HARTLEY, K.C.V.O., F.R.S.
564	THE RADIO SECTION DISCUSS MATERIALS FOR VALVES
566	THE HISTORY OF ELECTRICAL ENGINEERING—4 *by* C. MACKECHNIE JARVIS
574	THE MEASUREMENTS SECTION DISCUSS SURGE DIVERTERS
576	PHYSICS, CHEMISTRY AND INSULATION *by* C. G. GARTON
581	HOME EVENTS
585	NEWS FROM ABROAD
586	AN EXHILARATING SUMMER GATHERING
596	DIGESTS OF PAPERS IN THE *PROCEEDINGS*
605	OBITUARY
607	MONOGRAPHS AND PAPERS PUBLISHED SEPARATELY THIS MONTH
608	SOME RECENT BOOKS
611	LIBRARY ACCESSIONS
612	ANNOUNCEMENTS TO MEMBERS
615	THE *JOURNAL* REFERENCE SECTION

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THE PROFESSIONAL ENGINEER AS ADMINISTRATOR

THE SECOND PRESIDENT OF THE SOCIETY OF TELEGRAPH engineers, as The Institution was known at the time of its inception, was Frank Ives Scudamore, who then held the office of Second Secretary to the Post Office. At that time electrical engineering was hardly recognized as a profession—certainly there were very few professional engineers in Government Departments—and it is interesting to know that one of the administrative heads of the Department operating the new service had found it desirable to don the mantle of an electrical engineer in his Department's interests. During the past 80 years professional engineers have grown into a numerous body, their status jealously guarded by The Institutions; they are comprehensively equipped as regards both scientific theory and engineering practice to exercise their professions in the public service. Here our purpose is to comment on the way in which, the pendulum having fully swung, the professional engineer is taking his share in administration, not only in the engineering industry and in technical operating organizations but increasingly in the public service and in the major industrial firms of the country.

To-day scientists and engineers in Government Departments with a considerable engineering interest, such as the Ministry of Supply, the Defence Departments and the Post Office, not only give advice when it is sought but as members of a team share in the formulation and execution of policies. The management of these Departments at the top has been likened somewhat to a Board of Directors drawn from the executives of a firm in which operations, supply, engineering and finance are all represented by those sitting round the table. The pattern for the Post Office was set in 1932 as a result of the recommendations of a committee of enquiry under Lord Bridgeman; for Departments responsible for national defence it was confirmed during the Second World War as a result of the revolution in weapons and the part played by the radio aids of the engineer-scientist in delivering and combating them.

A corresponding pattern is to be seen in the Boards of the major operating organizations in fields as diverse as those of the British Broadcasting Corporation and the National Coal Board, and in enterprises as varied as the oil, the heavy chemical and the metallurgical industries and enterprises concerned with spinning and weaving of the new synthetic yarns.

The senior engineers and scientists who occupy these high-level posts in the public service and in industry remain for the most part clearly identified with their respective fields of technical responsibility, and many, indeed, would not relish the abandonment of the practice of their profession in favour of administrative work. In the engineering industry some senior managerial and administrative posts are commonly held by engineers, and this is now true also in at least one part of the public service. However, as recently pointed out by the Advisory Council on Scientific Policy, it is important, if we are to adjust ourselves to current trends, that more men with scientific training should be employed at the top in industry as a whole and in the Civil Service. Traditionally, entry into the administrative hierarchy of the Civil Service has been by way of a classical education and the humanities, though entry has in fact been open to those with academic scientific training; now administration is to be reinforced by men who have learned scientific theory in the engineering schools and who have had day-to-day experience of practical problems requiring professional engineering ability for their solution. With the increasing dependence of our everyday pursuits on technological advances, the advantages of this course will be apparent.

It is controversial whether the engineer who, with a successful professional career behind him, turns to administration, requires some special supplementary training for his new assignment. It is essential that he should have ability; success in the administration of an industrial organization or a Government Department is unlikely to come to the man who has failed to make his

mark while an engineer. Granted that an engineer turned administrator has this ability, that he has as much readiness to deal with human reactions as with the reactions of material things, and is receptive of the techniques of his new profession, he would be wise to recall at times John Hopkinson's oft-quoted dictum that "What is wanted is not to depend on mathematics alone, but to have a general appreciation of when a thing looks about right." Such a man will not fail when he leaves the engine-room for the bridge, whether time allows him the opportunity for a special course or not. It is indeed endemic in The Institution's training policy that a broad education and professional training should of themselves enable the right men to fill—in the fullness of time—the highest posts that industry, the Civil Service, and public administration have to offer. This is not to decry "training for management" for engineers of the right stamp for future leaders will always profit by it; in pursuit of this, we would suggest that more employers might usefully send their outstanding younger engineers on the three-month courses held at the Administrative Staff College, Henley. Such courses are well suited for the needs of first-class men whose outlook is shifting from a narrow field of technology to the broader slopes of human relations.

Whatever his training and experience, let the engineer, and particularly he who would become a competent administrator, not forget that a particular brand of applied science is only a very small, although often a very useful, part of the total sum of human knowledge. Much of this total knowledge is probably useful at one time or another in controlling one's fellow men, and well equipped is the engineer-administrator who has had the time and inclination to acquire a balanced sample of it in greater measure than his professional training and experience have strictly necessitated. A little learning may be dangerous, but for the man in control no learning at all is more so.

The International Electrotechnical Commission

THE 20th General Meeting of the International Electrotechnical Commission, the first to be held in this country since 1938, took place in London from the 28th June to the 9th July, 1955. The delegates, numbering about 500 and representing 26 countries, were the guests of the British Standards Institution, and nearly 30 technical committees held meetings at British Standards House.

The Council of the Commission, meeting on the 8th July, elected Dr. P. Dunsheath (United Kingdom), Past-President of this Institution, to the Presidency in succession to Dr. H. S. Osborne (United States), whose three-year term of office has expired, and Dr. A. Roth (Switzerland) to the Treasurership in succession to Dr. Dunsheath.

The programme arranged for the General Meeting included a reception at Savoy Place, at which delegates, after being welcomed by the President of The Institution, inspected a collection of old manuscripts, rare books and Faraday's notebooks and letters, and, by way of contrast, were shown *The Inquiring Mind*. There were two other functions of particular interest: a lecture at the Royal Institution and a banquet at Guildhall attended by the Lord Mayor.

The Charles le Maistre Memorial, in the form of an annual lecture on some aspect of standardization was instituted by the Committee of Action of the I.E.C. in July, 1953. Its object is primarily to perpetuate the memory of Mr. le Maistre's 49 years of outstanding service to the Commission and at the same time to contribute to the progress of international electrical standardization through the activities of the I.E.C. M. Andre Lange, a close friend of Mr. le Maistre for many years, gave this, the first, lecture under the title "Charles le Maistre: His Work, the I.E.C."; he described the development of the Commission and the great personal contribution Mr. le Maistre had made to it. Those who knew le Maistre will derive much pleasure from reading the text of the lecture, which is published by the Commission's Central Office in Geneva.

At Guildhall, Lord Waverley, referring to the merchant and craft guilds in the Middle Ages, said that in the era of mass production there must be some lessening of the intense personal pride of the craftsman in the work of his own fingers, but it must never be said that this pride in workmanship has gone. The Lord Mayor said it was fallacious, though understandable after the enormous developments of this century, to look for a short cut to a general improvement in material conditions and in the relationships of life. The signs of a nation's health were its civic morality, its administration of the law, the influence of the Churches, the tone of its Press, the freedom of its Universities and the conduct of its sport. Praising the work of the Commission and stressing the value of international co-operation, Mr. Peter Thorneycroft, President of the Board of Trade, said we faced to-day a combination of factors likely to bring about dramatic alterations in our standard of living—atomic power on the one hand and the possibility of automatic factories on the other. The role of Governments was to create the conditions in which these great changes could go smoothly forward: he sensed an intention to do this, whether in London or Paris, Geneva or Washington. On behalf of the Commission Dr. Osborne spoke with feeling of the British tradition and the hospitality of the delegates' hosts.

The First Graham Clark Lecture

"The Engineer's Contribution to the Conservation of Natural Resources"

The Lecture was delivered by Sir Harold Hartley, K.C.V.O., F.R.S., in the building of The Institution of Civil Engineers on the 4th May, 1955

IT is my privilege this afternoon to give the first Graham Clark Lecture, and it is appropriate that I should begin by paying a tribute to the man whom these lectures commemorate and whose idea they were. I first met Graham Clark when I gave the James Forrest Lecture in 1933 and from then onwards, like so many of you, I had to thank him for constant acts of kindness and courtesy. The Secretaries of the Institutions, if they are wise, can exert great influence on policy, and this was certainly true of Graham Clark. But apart from all he did for the well-being of The Institution of Civil Engineers for 17 years as Secretary, his most important contribution was his insistence on the essential unity of the engineering profession. He saw so clearly that with the inevitable increase of specialization there was an increasing need to secure a common understanding and sympathy, as any great engineering work was bound to be a combined operation. This is an aspect to which I shall return in my lecture more than once. And as a means of fostering this mutual understanding Graham Clark suggested these lectures on subjects of common interest to the three Institutions. As it was for 15 years my own task to co-ordinate the work of civil, mechanical, electrical, marine, signal and road-motor engineers and to provide a common research service, I share his point of view.

Graham Clark was constantly thinking out means of strengthening the bonds between the Institutions and of forging new links with the engineers of other countries. With the experience of the war he and his colleagues set out to form the Commonwealth body which first met in 1946. A year later, taking advantage of the proposals of the second oldest engineering body in the world—the Royal Dutch Institution—they embarked on the formation of the European and American Conference, when Graham Clark's fluent French was of great assistance. Those are some of his constructive contributions which this lecture is meant to keep in mind.

Scope of the Lecture

When I came to consider the title of this lecture I was faced with a certain dilemma, for it is the ingenuity and initiative of the engineer in satisfying the growing demands of the world by new inventions and in revolutionizing our way of living which have stepped up the consumption of natural resources so that the ever-growing inroads upon them have now become a matter of serious concern. In 1828 Thomas Tredgold defined engineering as "the art of directing the sources of power of Nature for the use and convenience of man." That still stands to-day if for "sources of power" we substitute the word in my title "resources," bearing in mind that since 1828 the profession of engineer has been continuously extended to include, besides civil engineering, mechanical, electrical and chemical engineering and all the other technologies which to-day administer to the comfort and well-being of mankind. I shall therefore interpret my title in the widest sense to include all these engineering technologies, as it is the intention of these lectures to commemorate the wide outlook of Graham Clark himself and his wish to see the Institutions co-operating on broad lines of policy. How am I to reconcile the idea of conservation with the steadily increasing consumption by the engineer of the world's natural resources? Now conservation is defined in the Oxford dictionary as "preservation from destructive influences, decay or waste." Excluding for the moment the raw materials which are the basis of all engineering production, what are the natural resources on which civilization has been built and which to-day are proving the limiting factors both in development and in supplying the world's food—its most crying need? The answer is soil and water. It is here that from the earliest times the engineer has made his basic contribution to the conservation of resources, and the material future of the world is very largely dependent on his continuous success in this field.

Water and the Irrigation Engineer

Water I put first, for it is essential to all forms of life and industry. You may remember the words of Robert Browning, standing at the window of his palace on the Grand Canal at Venice when a total abstainer was extolling the virtues of water. "Water," said Browning, "as you see, for purposes of locomotion most convenient, for washing indispensable, but to drink, God forbid." Be that as it may, water is proving more and more the indispensable resource on which plans so often have to be based, and its conservation has the highest priority. Without it soil becomes a desert, production an impossibility. But water is also a potent source of destruction and a carrier of disease, and so the engineer has here a dual task.

We are dependent for fresh water on rainfall, on lakes, rivers and springs, on underground and man-made reservoirs, and for salt water on the sea. Thanks to the sun's radiation there is a continuous cycle of evaporation and rainfall; 98% of the earth's water is in the sea; 98% of the rest is frozen in the polar ice caps; only 0·04% of the whole is in the rivers and lakes, and only one part in 100000 is involved in the hydrologic cycle in the atmosphere on which life depends. The formation of soil is dependent on the weathering action of water and ice on the rocks; some soils are wind-blown but most are formed by water-borne alluvium. That is the raw material on which in prehistoric times the living assemblage which constitutes fertile soil developed, with its vast population of micro-organisms, fungi, algae, protozoa and bacteria, of which there are many millions in a gramme of soil. Then Nature took a hand in conserving this precious material with her forests on the slopes, their deep roots absorbing and holding the water and protecting the soil against the run-off. On the plains, the prairies and pampas of North and South America, grass held the soil and gave it permanence. The coming of man, his interference with Nature's conservation, the felling of the trees and the ploughing of the plains made problems for the engineer to grapple with.

What was the engineer's contribution in the oldest centres of civilization? They were not situated in the temperate zone with its kindly rainfall, but in the rainless semi-arid zones of Mesopotamia and Egypt, and their existence was dependent on the irrigation engineer. It was the early skill of the irrigation engineer that made possible the temples and pyramids of Egypt and the hanging gardens of Babylon. In Egypt irrigation dates from the Old Kingdom, possibly as early as 3000 B.C., when embankments were built partly as a flood protection and partly to form a reservoir. From this developed a system of basin irrigation from the Nile flood with terraced basins all the way from Aswan to the sea. In Mesopotamia the Sumerians fertilized their fields by irrigation trenches as early as 5000 B.C. and there is an inscription recording the irrigation schemes of Hammurabi, the founder of the Babylonian Empire, in the year 2000 B.C. The fertility of Babylonia became a source of envy and astonishment to the Greeks. Later Sennacherib built a great aqueduct, 50 miles long, to bring water to Nineveh and to irrigate the orchards and gardens outside the city wall. It was as wide as an arterial road and paved with masonry; a dam with sluice gates regulated the flow and enabled water to be stored. These early irrigation engineers were most skilful in the design and control of their large canal systems. The Nahrwan canal, running for 200 miles parallel with the Tigris, and many like it, rivalled the largest modern works in their boldness of conception. They knew in those days how to divert rivers by dams and to dig great artificial canals to lead the rivers into their irrigation systems and to avoid the risks of erosion and silt.

The great cities like Ur of the Chaldees were dependent on water, and when the Euphrates shifted its course and the network of irrigation canals was emptied Ur was abandoned and left to become the impressive heap of ruins we fly over to-day. Others, like Babylon, Nineveh and Ctesiphon, were more fortunate, and their irrigation systems continued as the basis of their fertility and wealth until the 13th century, when they were destroyed by the Mongol invaders, and Mesopotamia became a land of ruins and desolation through which great waters ran to waste or overflowed their banks to make malarial swamps.

In the Roman Empire water was carried in great aqueducts on arches wherever it was needed, and when an aqueduct had to cross a valley on tiers of arches, like the Pont du Gard at Nîmes, the relative positions of the arches were structurally correct.

I well remember the first time I realized what water meant to man. After a long ride on an obstinate mule through the sandy foothills of the northern range of mountains in Cyprus, we suddenly came over a rise to the village of Kythraea, with its beautiful orchards in full bloom. We sat down to eat lunch at a great spring, the source of that fertility, and across the plain of the Mesaoria one could trace the abutments of the aqueduct that carried that water to Salamis in the days when St. Paul landed there. The aqueduct has perished and Salamis is a wilderness of wattle.

In India the Mogul emperors extended the irrigation schemes of their predecessors in the arid plains of the Indus and Ganges, but their declining empire was unequal to the maintenance and administration of the complex system, and so the canals became choked with silt and fell into disuse until the coming of the British in the 19th century and the rebirth of irrigation engineering. By 1830 the engineers of the East India Company had reopened the old Delhi and Jumna canals in the North and were improving the ancient irrigation works in the Cauvery delta in the South. Many lessons were learnt of the behaviour of water and the problems of scour and silt, and when the famine of 1832 had intensified the need for more water, Proby Cautley in the North and Arthur Cotton in the South, two great pioneers, were able to embark on the large projects which laid the foundation of modern irrigation engineering. Cautley's 300-mile Ganges canal with its great Solani aqueduct still ranks as one of the major irrigation schemes of the world. Then followed a long series of hydraulic projects all over India, which greatly increased the area of fertile land and provided the experience on which later developments in Egypt, Mesopotamia and other parts of the world were based.

The Multi-Purpose Water Schemes

Meanwhile hydro-electric power and the advance in engineering techniques made possible the multi-purpose schemes for water control, with their objectives of flood control, power supply, irrigation and transport.

The Tennessee valley, with its 27 dams and reservoirs controlling a river basin of 40000 square miles, is one of

the most comprehensive of these schemes and has been completed long enough to justify what was claimed for it. The valley has an ample rainfall, and so the objectives were flood control, power and communication. The reservoirs provide 11½ million acre-ft of storage for flood control at the beginning of the flood season and have prevented an immense amount of flood damage each year. Six million acres of rich bottom-land is protected in this way. The replanting of the slopes has stopped soil erosion, made the muddy streams clear again and delayed the silting of the reservoirs. The Tennessee Valley project brought new life into a depressed area and did much to raise its standard of living.

The great dams and reservoirs on the American rivers flowing to the west, like the Grand Coulee, the Shasta and the Hoover dams, are more spectacular and serve the additional purpose of the irrigation of millions of acres of rich agricultural land.

In Canada, the Kemano–Kitimat project came into operation last year. In this a string of rivers and lakes has been dammed into a 150-mile reservoir and the flow of the water diverted from east to west. The backed-up water then drops through a 10-mile tunnel in the mountains to the power station at Kemano, which has a capacity of 330 000 kW. This will be increased later to 1·7 million kW. The power is transmitted 49 miles to Kitimat, where it is used in the aluminium smelter.

Similar schemes with the same objectives are going forward in many other parts of the world. It is interesting that the first major arch dam to be designed by British engineers is on a tributary of the Tigris, the earliest home of irrigation. The Dokan dam on the Lesser Zab river, now under construction, will help to control the floods of the Tigris and with a subsidiary barrage will provide irrigation for 2 000 sq. miles of desert area. It will have a storage capacity of about 5 million acre-ft and a hydro-electric power potential of 143 000 kW.

In Africa, there are the Volta river and the Shire Valley projects. On the Volta river there are no substantial falls to facilitate the production of hydro-electric power, and so the scheme takes the form of a large rockfill dam, over 300 ft high, across the river at Ajena, which would impound an artificial lake some 3 000 sq. miles in area and 300 miles in length. The head is entirely that produced by the dam itself and the power station would provide an average continuous output of 580 000 kW. The power would be transmitted to a smelter downstream, where it is planned to produce some 210 000 tons of aluminium ingot per annum. The scheme would provide power for other parts of the country, inland navigation on the lake, and irrigation water for at least 200 000 acres of fertile land on the Accra plains.

The report on the Shire river project, which has just been published by the Nyasaland Government, describes a most interesting multi-purpose scheme. It provides for control of Lake Nyasa and the Shire river by a seasonal bund on the river south of the lake, and a series of hydro-electric and flood-control schemes lower down the river with a peak capacity of 360 000 kW. The control of the river would enable large areas of marsh land to be drained and other promising areas to be irrigated. The reclaimed land could be used for the intensive cultivation of cash crops such as rice, and the provision of power would encourage local industries. The scheme would open up a vast inland water-transport system where transport is badly needed, and it would do much to raise the standard of living and productivity.

Another good example of the engineer's contribution to conservation is the Snowy river scheme in Australia. The Snowy river, rising on the eastern slopes of the Snowy mountains, flows southward through country with an adequate rainfall for agriculture and wastes its great flow of water in the sea. On the western slopes of the Snowy mountains there rise the streams that unite to form the Murray river, which flows through hundreds of miles of arid plains before reaching the sea in South Australia. By building dams in the mountains great volumes of water will be impounded, one reservoir will store seven times the volume of water in Sydney harbour, and then this water will be diverted by tunnels through the mountains to feed the Murray river system with two million acre-ft per annum of irrigation water, which in its flow through 17 power stations will generate 3 million kW. The first power station is nearly finished and this huge scheme when completed will provide Australia with two of her greatest needs for development, power and water, for she is one of the driest countries in the world.

It would be easy to multiply examples; just one more that I have seen occurs to me—to show what the engineer can contribute in the remote districts of the world. The Warsak dam and power station on the Kabul river in the North-West Frontier Province of Pakistan, now under construction, will provide 60 000 kW of power and will irrigate 60 000 acres adjoining the arid mountainous country of the Khyber pass. It will offer a new kind of existence to those wild frontier tribes, the Afridis and Mohmands.

Silt

There is another side to the picture. With the speed with which man is now changing his own environment he is apt to forget that the slow evolution of Nature herself is still proceeding. The forces that smoothed the profile of our planet and produced the soil from rocks are still in action. Thousands of millions of tons of rock particles and eroded soils pass down the rivers each year, especially in flood seasons, since the carrying capacity of moving water varies as the sixth power of its velocity. That is the main anxiety of the dam builder for its future, and he is faced with the dilemma that the more he uses a reservoir for flood control the shorter will be its life. In 200 years the great Lake Mead above the Hoover dam will be an alluvial plain, and the lives of many reservoirs can be reckoned at a century or less. The Aswan dam stands out for special reasons as almost unchanging.

Here the engineer becomes an agronomist, since forestation, ground cover and terracing can go far to prevent soil erosion and muddy streams. Subsidiary silt catchments can be built upstream, but their life is limited. The problem of the deposit of silt in the reservoirs when the stream velocity is diminished is being studied, and the persistence of a denser stream of water loaded with mineral particles along the bottom of the reservoir has raised hopes that by opening sluices at the bottom of the dam in flood time the deposit will be reduced, but their scouring action is very local. Silt is the great problem of the future for the hydraulic engineer, because with the loss of storage capacity the output of a power station will become more and more dependent on the seasonal flow, and more serious still will be the loss of perennial irrigation where it is dependent on storage. The ultimate solution may be new high dams, but the best sites have already been chosen.

Improved Techniques

Let me now turn for a moment to the improved techniques the engineer has evolved in methods of surveying, dam construction and model studies, which have helped so much in the quick development of these bold hydraulic projects.

Surveys

The engineer's first requirement is an accurate survey, and flying has revolutionized the methods of large-scale surveying, for, by the use of aerial photography with stereoscopic cameras to trace the contour lines, the preliminary work of mapping new schemes can be done with great speed and accuracy of detail. The nature of the rock and soil, soil erosion, forest cover and changes in the flow of rivers can be surveyed over wide areas with a completeness that was formerly impossible. For instance, 30000 sq. miles of country were mapped in connection with the Kariba and Kafue hydro-electric schemes on the Zambesi, and 16000 sq. miles for the Volta river scheme in the Gold Coast.

Again, in these great schemes an accurate knowledge of the form of the underlying strata is an essential preliminary to engineering design. Modern geophysical methods enable it to be obtained with great savings of time and effort. The measurement of the time taken by seismic waves, set up by an explosion, to travel directly or after refraction through the underlying rock enables the depth of the bedrock at various points to be determined with an error within 10%. This method was used in the survey of the 300 yd-wide rocky gorge of the Kabul river for the Warsak scheme, and it saved a large amount of difficult drilling.

The electrical resistance of soil and subsoil depends largely on its moisture content and it varies from rock to rock; so resistance measurements between different points are another means of determining underground conditions and the existence and depth of a water table. This method was used in the survey of the dam site in the Kariba Gorge on the Zambesi.

These are two examples of the progress that is being made in the application of geophysical methods in engineering, which, together with the new science of soil mechanics, have contributed so much to the rapid design of these large multi-purpose water schemes.

Dam Design and Construction

The progress of concrete design and construction, which has replaced the masonry dams of earlier times, has given us simplicity and grace in the great structures which are adding so quickly to the number of vast reservoirs in the world. This advance has come partly from the scientific analysis of the stresses in the structure, partly from the experience gained in methods of rapid construction by the diversion of water and boring of great rock tunnels, partly from the progress in our knowledge of the properties of concrete and partly from the improved mechanical methods of making and placement of the concrete in large quantities, which in the Grand Coulee dam reached 20000 tons a day. Then there are the methods of reducing the temperature rise during setting by the use of low-heat cements and the admixture of pulverized fuel ash, a pozzolanic material; the removal of the accumulated heat by refrigeration or circulating water; and the "case-hardening" of the outer surface of the concrete on the spill-way sectors by vacuum application to remove air bubbles and water. The organization of these projects, the selection and transport of materials and the co-operation of civil, mechanical and electrical engineers constitute a combined operation of great magnitude, and its success in so many parts of the world is a triumph for the engineer.

Hydraulic Models

These great engineering works involve an interference with nature, and experience has taught us that whenever we interfere with nature we must watch her reactions very closely with all the help that science can give. In no field is this more important than in interference with the flow of water. Changes of conditions brought about by new engineering works in a river channel, in a harbour or in coast defences may produce most unexpected results, and the number of independent variables involved is usually too great for a theoretical prediction. Luckily, the technique of using scale models in which the effects of changed conditions can be speeded up a thousandfold is now sufficiently advanced to enable a fairly accurate forecast to be made if the model is well planned and its limitations are clearly recognized. No model can reproduce in detail all the conditions of the original; for instance, the size of the bed material in moving-bed models cannot be scaled down to correspond with the other dimensions, and corrections have to be made when the similitude is imperfect. There is thus a limit to what can be expected of a model and great

experience is needed in its use. However, the justification of the use of models has been established in many cases by a comparison of their results with those found subsequently when the work has been carried out. The model enables a comparison to be made of various engineering solutions of a problem and thus helps in the selection of the most economical design. The cost of the model is a very small fraction of the total sum involved.

Theoretical studies are also of importance for future developments, for instance Hawthorne's analysis of the secondary flow around struts. Experiments in a hydraulic channel showed that the scouring of the beds of rivers near obstacles may be attributed to secondary flow and that the scouring is less marked with a bicusped, than with an elliptical, profile.

The first experiments with loose boundary models were carried out by Osborne Reynolds in 1885 in connection with proposals for improving the approaches of the Mersey. He showed that such models, even if they were very small—with a horizontal scale of 1 : 10 600 and a vertical scale of 1 : 396—roughly reproduced what was happening in the estuary. Later his techniques were developed by Gibson for river and estuary flow and drift.

Subsequently, many model laboratories were established on the Continent, especially in Germany, and from 1929 the Vicksburg experimental station and several others were started in the United States. The Delft station dates from 1933, and Grenoble came into the model field in 1940. In 1919, experiments carried out at Poona by Claude Inglis with loose boundary models of various sizes showed that the changes which occur in nature can be reproduced only in very-large-scale models, and since then large numbers of such models have been constructed in India, and now, at long last, we have our own hydraulics station at Wallingford. Model studies are now almost invariably a condition of the contract for major hydraulic works, and consequently the provision of adequate facilities at the Wallingford station is a matter of serious concern in the oversea contracts on which the trade balance of the United Kingdom is increasingly dependent. This does seem to me an issue that concerns all three Institutions.

Irrigation and its Problems

The present land area in the world cultivated for food is about 1 620 million acres, and of this 230 million acres are under irrigation, much of it perennial, and these acres are of special value since they grow more than one crop a year under semi-tropical conditions. It may be possible to double this irrigated area in places where water is the limiting factor in cultivation, as in India, for example, where only 6% of the river flow is used in this way. Spraying is a much more efficient use of water than surface distribution as it can be controlled and the right amount of water applied when it is most needed. Much progress has been made with spraying in Arizona, where water is precious and where the cost of the equipment is outweighed by the increased crop yields.

But irrigation is another interference with nature, and the engineer's task is not finished when he has provided the irrigation water, since it brings with it the danger of salinity and alkaline soils, a danger now threatening large areas in the Punjab. All irrigation water contains some salt, which is also present in the soil, and unless there is efficient natural or artificial drainage the salt will accumulate and the soils may become alkaline and lose their structure. In Egypt, where there is perennial irrigation, drainage canals carry off the surplus water, and standing in a cotton field in the Delta I have seen salt crystals growing in the drainage canal ten feet below the level of the crop, so small is the margin of safety. The salt water from the drainage canals is finally lifted into the Mediterranean. In the Punjab, 500 miles from the sea, conditions are much more difficult. More water, either from canals or tube wells, is needed to leach the salt from the soil, but some system of drainage and disposal of the drainage water on derelict land seems inevitable and represents a problem for the engineer. The same difficulty arose in the irrigated lands of Arizona; it was solved by drainage schemes, but it will recur elsewhere whenever irrigation is installed without precautions.

The Yangtse river in China provides, I am told, an example of a special type of irrigation which has been in existence for 2000 years. Water is drawn off at favourable points into irrigation canals and distributed to the land, and the drainage water is returned to the river, in which the volume of flow is sufficient to render the added salinity innocuous. The advantage of this method, when the lie of the land permits it and the steady flow of water in the main stream is sufficiently great, is its permanence. It illustrates, too, the important principle of not attempting to use irrigation water for a larger area than all the circumstances justify.

Irrigation remains a complex problem. Pumping from tube wells under suitable conditions may help to solve it, but before reliance can be placed on this a survey of the underground water resources and their quality is essential, and a careful watch must be kept to see that they are not depleted. There is, too, a risk of changing quality, as in the United Provinces, where after six years the water from the wells became brackish and useless. Water is so precious that this method should be regarded only as a second line of defence where it is possible to impound water from the maximum flow of rivers, as, for example, the Indus, by engineering works in the Himalayas that would not only provide perennial irrigation for great areas and power supplies, but also diminish the risk of floods and soil erosion.

We need to know much more about the movement of water in the soil, much more about underground water resources and much more about the possibilities of multi-purpose water schemes which would utilize the world's limited supply of fresh water to the best advantage.

The Future of Water Supplies

So far, I have dealt mainly with water in relation to agriculture. There is the wider question of our ability to meet the rapidly increasing consumption of water in the cities and by industry. In some places water is becoming the limiting factor to development and in Britain it is already difficult to locate a new industry needing much clean water or to find inland sites with cooling water for power stations and industry. Nuclear power stations will almost certainly be sited on the coast for this reason. The amounts required by modern industry are large—a million gallons to make a ton of viscose yarn, and 400 000 gallons a ton of steel. Here the engineer can help by the efficient treatment of effluents and sewage, by the re-use of water by means of cooling towers, or by returning well water used for cooling to the strata from which it was drawn. Even in Britain water is needed for irrigation south of a line from the Severn to the Humber if maximum crop yields are to be obtained. And I must not forget to mention the engineer's contribution to the conservation of human life and the prevention of disease by sanitation and the provision of pure water.

In the United States the threat of water shortages has directed much attention recently to the problem of the increasing demand. The Conservation Foundation has directed its main efforts into this field, and five major studies* have recently been published dealing with various aspects. Statistics show that 72% of the precipitation in the United States is returned to the atmosphere by evaporation or transpiration through plant leaves, leaving 28% to reach the sea by rivers. Some 25% of the water consumed is drawn from underground reservoirs, and in many places the water table is falling so that both on the eastern and western seaboards salt water is seeping in from the sea and damaging vegetation. One study on the conservation of ground water shows the need for much closer knowledge of the underground reservoirs and the movement of ground water to replenish them, in order to regulate their use.

Although the total resources in the United States are sufficient, it is clear that their effective utilization will be a serious factor in future planning, to which surveys of climate and water flow are an essential preliminary.

Another study examines the prospect of getting water from the sea by various means—freezing, distillation and electrolysis—and the prospects seem to be most favourable for the purification of water by electrolysis between ion-exchange membranes. In large units the cost may be reduced to 2s. per 1 000 gallons if a large sum is first spent on development.

The effort devoted to these studies shows the urgency of the problem for the engineer—not only in the United States but elsewhere.

* THOMAS, H. E.: "The Conservation of Ground Water" (McGraw-Hill, 1951).
"Water in Industry" (The Conservation Foundation and The National Association of Manufacturers, 1950).
COLMAN, E. A.: "Vegetation and Watershed Management" (Ronald Press, New York, 1953).
ELLIS, C. B.: "Fresh Water from the Ocean" (Ronald Press, New York, 1954).
LEOPOLD, L. B., and MADDOCK, T., JR.: "The Flood Control Controversy" (Ronald Press, New York, 1954).

Land Conservation and Reclamation

I have already touched on the conservation of soil by measures to prevent erosion, flooding and salinity. Now I come to the wider problems of land conservation and reclamation. In some places Nature is encroaching on the land by coastal erosion; in others she is adding to the land areas by depositing silt at the mouths of rivers. These two effects are said largely to balance one another, but it is the engineer's task to prevent the one and take advantage of the other so as to increase the land area. Coastal erosion is slow but continuous; protection against it is difficult and costly, and consequently it is undertaken mainly to protect industrial and residential sites or to guard against the danger of the flooding of large areas of agricultural land by high tides and surges. Jean Ingelow's poem "The High Tide on the Coast of Lincolnshire" gives a vivid picture of what has occurred in the past; we had a sharp reminder in the disaster of 1953.

Holland, more than any country, is at the mercy of the sea, as 40% of the land is below sea level, and there the techniques of protection by sea walls and sand dunes have been the subject of constant research and study. There again soil mechanics is most helpful and the study of the most effective plant and tree cover is leading to the most economical solution. This was dealt with in such detail in the proceedings of The Institution of Civil Engineers' Conference on Biology and Civil Engineering in 1948 that I need not do more than mention here the contribution which these studies are making to land conservation. It is one of the important partnerships of man and Nature.

In coastal protection, model work is again indispensable in showing the effects, sometimes most unexpected, produced by sea walls or groins, so that they can be designed effectively and with economy. The force of water is so strong and its effects so disastrous that the protection of land against floods from sea and river must always remain a major task of the engineer.

At the mouths of some great rivers, like the Ganges and the Nile, Nature through the ages has built up large areas of fertile land in their deltas without the aid of man. But in countries like Britain and Holland, where land is precious, man cannot wait and must help with reclamation.

In Britain the great reclamation by drainage of the southern fens by the "Adventurers" in the 17th century added 600 000 acres of the most productive land in the country, mostly below high-water level, so that its existence depends on the maintenance of sea walls, river banks and drainage. Since then some 75 000 acres of The Wash have been reclaimed when and where there was a silt deposit covering the sand, which justified the cost of a new sea wall and drainage.

The history of Holland is a long fight against a slowly rising sea level to preserve the land by sea and river dykes. The Zuider Zee was lost to the sea as late as the Middle Ages, since when there has been a gradual reclamation of the land. Inland lakes have been

drained and cultivated, and in 1927 the great Zuider Zee project was started. With the closing of the 20-mile dam across its northern entrance it ceased to be a sea and became a fresh-water lake, the Isselmeer, in the middle of Holland, which can supply water to the surrounding districts in prolonged periods of dry weather. This is being followed by enclosing or impoldering five successive areas with dykes behind the dam, which will add over half a million acres to the cultivated area of Holland when the water has been pumped from them. The gradual accumulation of silt in these areas is being accelerated by the hybrid grass *spartina townsendii*, imported from England. This grass was first noticed by Lord Balfour of Burleigh in 1899, in Poole Harbour. He brought it to the notice of Francis Oliver, who soon realized its potentialities for artificial reclamation, for it will grow in brackish water and, by slowing down the currents, hastens the deposition of silt and its subsequent consolidation.

The policy of the Dutch has always been to shorten their coastline and so reduce the risk of floods. After the disaster of 1953 they decided to embark on the "Delta Project" of building dams across the tideway entrances to the great rivers in the south, which when complete will halve the coastline that has to be protected.

Another country in which the richest soil is below sea level and must be protected by sea-walls and by pumping is British Guiana, where the development originated by the Dutch has been maintained by British engineers.

The Imperial Valley in California may before long present a special problem of land conservation. Thanks to irrigation, the valley, which was once a desert, is now most fertile, growing three or four crops a year. The whole of it is below sea level and it owes its protection against the Pacific Ocean to the natural barrier which had been created by the deposits from the Colorado river in former ages. Each year coast erosion removes a large amount of the barrier, but until recently the barrier has been maintained by the silt of the Colorado which balanced the erosion of the sea. Now that the silt is being deposited in Lake Mead the barrier is being gradually reduced. In 1940, only five years after the construction of the Boulder dam, the Gulf of California had advanced by 25 kilometres. This is another case of man's interference with Nature, and the problem is made more difficult by the fact that the erosion is taking place, not in the United States, but on Mexican territory.

And next there comes the cultivation of the land, when conservation means the raising of crops without the loss of soil fertility. It is only too easy to raise crops at the cost of fertility. And here, since mechanization has invaded agriculture, the task of soil conservation falls largely to the agricultural engineer. Britain has now the most highly mechanized farming in the world, and thanks to this the annual productivity is £660 per man employed.

Every type of soil and climate presents a special problem, and it is for the engineer to provide the implements and methods which will optimize the yields of crops while maintaining the fertility of the soil. Water again is the limiting factor and I have already touched on the economy and advantages of spray irrigation, which we owe to the engineer. Its great advantage is that it can provide the right amount of water when it is needed. Penman has shown that the loss of water from the soil by transpiration depends mainly on solar radiation, and in Britain this corresponds closely with the sunshine hours per month. The Meteorological Office now publishes monthly potential transpiration figures for the more important farming districts of the country, to help farmers in deciding how much water is needed to make up for deficit in rain. With spray irrigation the use of water thus becomes more scientific and economical and the size of droplets can be regulated not to exceed 2 mm in diameter. Large drops break up the soil particles and consolidate them, reducing the porosity of the soil. The provision of economical drainage is another problem for the engineer.

We are learning gradually how to make the best use of Nature's gifts and under what conditions land is best devoted to forestry, grass cover or arable crops. In all this, engineering and soil mechanics are vital factors, and on the engineer's contribution to mechanization and conservation will depend more and more the ability of the world to feed itself in the future.

Energy

Next to soil and water I rank energy as the third great need of mankind, since statistics show that the consumption of energy *per caput* determines the standard of living of a country. Here the engineer, by his increasing use of water power, is drawing on revenue and not on capital resources, though water power provides only 4 or 5% of the world's energy consumption. Other revenue resources are solar radiation, wind, tidal energy, geothermal heat and the burning of timber and vegetable products. The last source provides some 18% of the total energy consumption to-day and there is not much prospect of any considerable contribution from the other revenue sources in the near future. Geothermal schemes in Italy and recently in New Zealand are of local importance, and the Bell Laboratory solar battery, with a 10% efficiency of conversion of solar-radiation energy to electricity, points the way to important developments.

The main contribution of the engineer hitherto has been the steady rise in the efficiency of combustion appliances, of the generation of electricity and of the gasification of coal. In the United Kingdom the increased demands for energy between 1920 and 1937 were met almost entirely by increased efficiency of energy conversion and utilization, representing a saving of at least 47 million tons of coal. There is no need to stress the importance of a continued effort for higher efficiency, but fortunately the possibilities of the nuclear power station have come just when there is little prospect of large additions to the output of coal. Here again is a combined operation for electrical, chemical, mechanical

and civil engineers which will multiply a hundredfold the world's energy resources. Important as electricity is for the production of heat and power, the importance of liquid fuel to our economy is hardly less, and the coming of nuclear power will enable the coal and oil resources to be used in the future more and more as a source of chemicals and of the liquid fuels on which for many purposes we depend.

We shall watch with envious eyes the great SASOL plant in South Africa just now coming into operation for making petrol and other products from coal costing 3s. 6d. per ton, the cheapest in the world.

Raw Materials

I come last to the engineer's contribution to the conservation of raw materials by added efficiency in their extraction, processing and use. It is a long story, which might easily become a wearisome catalogue—so let me select a few of the outstanding examples and particularly those of special significance for the future.

Extractive Metallurgy

We are living in a metal civilization, and in spite of the progress being made in the use of plastics and bonded materials as alternatives we must look to an increasing use of metals in the future. For many engineering purposes they are indispensable, and progress in metallurgy is often the limiting factor in engineering design. All recent recorded surveys of resources, like the Paley Report, make it clear that we shall become increasingly dependent on lower-grade ores containing several finely intergrown minerals, which must be separated. For the treatment of such ores the older physical methods of ore dressing, producing concentrates for smelting, are proving inadequate, and they are now being supplemented by various chemical engineering techniques. There are two main developments. In one the metals are leached out by various solvents, sometimes under pressure, and then separated by different methods—precipitation, electrolysis, or ion exchange, as with uranium. For example, a large ore deposit containing less than 1% of copper oxide is being leached with sulphuric acid. Bacterial oxidation of a low-grade, partly oxidized copper-sulphide deposit is being tried with the same object. Nickel sulphide concentrates are being leached with aqueous ammonia and oxygen under pressure. The other method consists in treating ores in fluidified beds at controlled temperatures with various gases. Iron oxide can be converted to magnetite for magnetic extraction, and sulphides of copper, nickel and cobalt can be roasted to sulphates for subsequent leaching with water. By temperature control an almost complete separation of copper from iron can be effected in this way.

The use of active carbon to extract metals from dilute solution has also considerable possibilities. For instance, gold can be extracted continuously with economy in the amount of cyanide required and with a considerable saving in the number of thickeners and continuous drum filters needed when the gold is recovered by precipitation with zinc dust.

The U.S. Bureau of Mines is carrying out large-scale experimental work on the chemical treatment of low-grade manganese ores by sulphating followed by leaching and precipitation. There are also possibilities of recovering manganese from open-hearth slag by fluidized-bed roasting followed by extraction with ammonia and ammonium carbonate.

Another important aspect of the chemical approach in attacking ore-treatment problems is the extraction of valuable minerals from the slimes which are often unavoidable and may carry sufficient of the ore to prevent the economic exploitation of a low-grade deposit. Selective flocculants are giving promising results and polyvalent ions are being used as flocculants in the recovery of uranium from enormous quantities of slimes produced in the treatment of Florida phosphates.

These new methods are likely to extend greatly the range of the ores that can be treated profitably, and thus increase the potential resources of metals in the world.

Hitherto, most of the development work in this new field has been done in the United States and Canada, where the exploitation of mineral wealth is a major part of the economy. The old distinction between the processes used in ore dressing and extractive metallurgy is disappearing with these chemical methods of ore treatment. In future there must be a much closer link between the schools of mining and chemical engineering in this country if we are to keep abreast of the times.

The Processing of Raw Materials and Synthetics

There is no better example of the great advances that have been made in the scientific processing of raw materials than the improvement in the refining of crude oil over the past 30 years. This improvement was responsible for the introduction of the fluidized bed, one of the revolutionary advances in modern techniques. By the improved design of stills, by better control and heat recovery, the overall thermal efficiency has been raised by 25%, the amount of refinery fuel required being less than 2% of the crude oil distilled. Then the amount of motor gasoline produced to-day by thermal reforming, catalytic cracking, polymerization of olefines and by other new techniques is, on a world basis, 36% by weight of the crude, as compared with 18% 30 years ago by straight distillation, and the octane number of the gasoline is much higher, with the resulting improvement in fuel economy.

Further, there has been a great advance in the range of products and their quality, to keep pace with technological progress, e.g. in the development of aero-engines. Synthetic detergents, paint additives, cutting oils and an immense range of lubricants are among the most significant advances. Propane and butane are sold as

"bottled gas" instead of being burnt as refinery fuel. A new aliphatic chemical industry has been built up, based on refinery gases, and platforming* adds largely to the supply of aromatic chemicals like benzene, which are now in such great demand.

There are many other parallel examples of this trend of modern industry to make better use of its new materials—rubber, cellulose, leather and, above all perhaps in importance, the scientific processing of food, which is now a great industry contributing much to the transport of food without deterioration and to its safe storage.

Synthetic materials in the 20th century have done much to change the pattern of our life and synthetic ammonia has relieved our anxiety about nitrogen fertilizers, which by increasing the output per acre are a most effective means of conservation. Plastics and synthetic fibres not only supply many new needs, but as substitutes for vegetable products they relieve the demand for them and thus leave more soil for food production. The output of rayon and viscose already exceeds that of wool.

But man's power to synthesize materials economically is limited to simple molecules and their polymers. There is no hope of his manufacturing the complex proteins and polysaccharides he needs for food without the aid of living organisms, which make them so accurately and cleanly by their template methods. Fermentation is one of the oldest industries, but it is only in this century that microbiology has revealed the almost unlimited possibilities of the living cell. From Pasteur and Koch the microbe got a bad name, but without it life on this planet could not exist. The microbe is a great conservator and it deserves a better reputation. The amount of nitrogen supplied to the soil by fertilizers is only a small fraction of that fixed by living organisms in the soil.

Rahn, in a comparative study of the criminology of the microbe and mankind in the United States, concluded that only one micro-organism in 30000 is a carrier of disease, while in the year of his census one inhabitant in 17000 was convicted of murder. And as Professor Kluyver pointed out in his Leeuwenhoek Lecture, the amount of microbial protoplasm in the world is probably 20 times as great as that of animal protoplasm, so that there is no lack of ready helpers with an amazing adaptability. The harnessing of micro-organisms in the production line in friendly tasks is one of the great ventures of the near future—biochemical engineering.

Structures

Among the great economies in the use the engineer makes of materials I put structures high on the list. I remember seeing, in 1901, the first skyscraper in New York, the old Flat Iron Building, soon to be dwarfed by the giants of the amazing Manhattan Island skyline. The foundations of great modern buildings are now designed on site studies using the techniques of the new science of soil mechanics. I have already touched on some of its new methods as applied to big dams, and as Dr. Lea dealt with them so thoroughly in his recent Unwin Lecture I need only refer you to this for the scientific methods that are now available to investigate the subsoil characteristics and for the various techniques for designing and constructing foundations on which buildings can be erected with economy and security. As a matter of interest I got the costs of a number of these site studies and they averaged about 0·2% of the costs of the buildings; some were as low as 0·03%.

Then in the structures themselves, steel and reinforced concrete with pre-stressed and often pre-cast units have made the main contributions to new designs and economies. Progress in the theory of structures based on the elastic limit of materials, in the quality of steel and in the fabrication of steel members, together with a wealth of accumulated experience, have produced large savings in the amount of steel required and in the cost of erection. I have a special interest here because one of the three steel-framed buildings which Dr. Baker, as he then was, investigated for the Steel Structures Research Committee, was one in which I was responsible for the co-ordination of the architects and the engineers. That investigation illustrates a principle I should like to adumbrate. Every major engineering project should be treated as an opportunity for research with the necessary scientific measurements, in order to correlate the predictions of design with the results obtained and to point the lessons for conservation. We did that at Euston House.

The results of Professor Baker's investigations showed the limitations of the elastic theory for practical use owing partly to its complexity in large structures and partly to the discrepancies observed in the stresses in the framed structures arising from the vagaries of riveted and bolted beam-to-structure connections. In structures designed by the elastic theory, some deformation must occur at working loads owing to stress concentrations and lack of fit during erection. Were it not for the ability of mild steel to undergo plastic deformation, such structures would prove unsatisfactory in service.

Professor Baker's development of the plastic theory of structures provides a basis for design in the calculation of ultimate strength and in so doing forces a realistic appreciation of the importance of ductility. One of the most important consequences of basing design on ultimate strength is that full use can then be made of the advantages of redundancy and of the rigid joint construction made possible by the modern development of welding. This leads on to the consideration of load factors instead of the old-fashioned factors of safety. Experience in the erection of single-storey buildings designed on the basis of the plastic theory shows economies of 15 to 30% as compared with similar buildings designed by orthodox elastic methods. The plastic method not only makes it possible to design buildings more economically but opens the way to the development of new structural forms in steel.

The increasing use of concrete in structures has

* A process for increasing molecular weight by a platinum catalyst.

helped the conservation of resources in two ways: first by its use in conservation schemes like coastal protection, harbours and dams, and secondly by the use of less valuable and more generally available raw materials in place of steel, with a consequential economy in coal.

A reinforced-concrete structure requires on an average about 40% of the weight of steel required by a normal steel structure, and the use of pre-stressed concrete in flexional members reduces the steel required to about one-seventh. In some structures (e.g. multi-storey buildings) the extra concrete required is almost negligible, but in others (e.g. bridges) the saving in steel has to be offset by an increase in the use of cement and aggregate. Even here, however, it may not be more than about 25% because the same amount of concrete is used for the foundations in both instances.

The economy of coal follows, since 35 cwt of coal are needed to make a ton of steel and 8 cwt to make a ton of cement. To the latter must be added the coal equivalent of the energy required in providing the average amount of 4 tons of aggregate, which must be added to one ton of cement in making concrete. Roughly, the replacement of a ton of steel by a ton of reinforced concrete may be said to save about a ton of coal.

The Working and Fabrication of Metals

I turn now to the great economies in material and effort that have resulted from the scientific development of the methods of working and fabricating metals and testing the quality of the product. The improved methods of welding, casting, pressing, extrusion, oxygen cutting, and machining have revolutionized metal fabrication, and the use of X-rays, gamma-rays, ultrasonics and other devices has enabled the products to be tested with much greater certainty. This is a steel age and the efficiency of the modern steel works and the continuous strip mill have made a great contribution to our economy.

Welding has had a most widespread effect through the ubiquity of its applications both to fabrication and repair. One has only to turn to the mechanized farming for an example of the value of an electric welder in repairing quickly a defect in a harvester in the critical days of gathering crops. Other applications of welding to repair are manifold. The various forms of electric welding—d.c., a.c., oxy-acetylene, argon arc, nitrogen arc, spot and butt have made it applicable to almost every metal, saved immense amounts of material and simplified construction by eliminating the need for rivets, gussets and overlap. In steel-framed buildings there are economies in materials up to 25% and the absence of rivet holes means that design can be based on the full sectional area of tension members. Welding is essential for the use of plastic design methods which require that all joints must be completely rigid. In bridges a welded design may show a saving of 25% over a riveted design and a transfer of many tons to the permissible live load. In ships there may be economies up to 17% of weight for an 18 000-ton tanker, with the advantage of the smooth contour of the welded hull and a corresponding saving in fuel consumption. The substitution of welding for the forging of pressure vessels has not only cheapened production but has made possible many improved designs.

Next to welding, improved precision methods of casting have contributed to great economies: centrifugal casting, die casting, shell moulding and the elegant lost-wax investment method for small castings. In the last-named a pattern is made by injecting wax into a die, the wax is then coated with a fine refractory and bonding agent and invested with a slurry of refractory which sets to form a mould. The wax is then melted out, the mould is fired and used for pressure casting. By this means intricate precision castings can be made with a fine finish, with a great reduction in the machining required and with an average saving of material of 50%. Gas-turbine and jet-engine compressor blades with their complex aerofoil sections and shapes can be made in this way much more cheaply than by machining them out of solid bars. The centrifugal casting of pipes gives a more uniform thickness of sounder metal and a high yield. Bearing-metal liners can be cast in by this means and require little or no final machining.

Improvements in machine tools have led to savings of labour rather than direct savings of material, and to greater accuracy and finer surface finish. Higher cutting speeds, to take advantage of carbide-tipped tools, and also greater flexibility of speed have been obtained by direct electrical drive with higher-powered motors. Higher speeds and improved quality of products have also been helped by research into the form of the cutting edge of the tool and by the provision by the metallurgist of new alloys better suited both to machining and to the work they have to do. While there has been much progress in automatic machines, the inclusion of the copying principle on standard machines has given them greater versatility and opened the way to repetition production at high speeds for large or small batches, when the use of a fully automatic machine would not be economical. Improvements in casting and drop forging enable work to be transferred directly to precision finishing machines with a high degree of accuracy.

The latest development is the automatic machine with electronic control and a computer which can read a drawing and translate it directly into work. That way lies the automatic factory of the future.

Wear and Corrosion

One of the major fields in the conservation of metals is the application of research to the problems of wear and corrosion. Bowden in his Hawksley Lecture showed how the contact of two metal surfaces invariably results in a transfer of particles of one metal to the other, and described the conditions under which various types of lubricants can minimize this transfer and loss of material. The action of the lubricant in diminishing friction results

in a saving of energy; friction in a motor car absorbs 20% of the motive power, but the major contribution of lubrication is in the saving of wear and in prolonging the life of the moving parts. Higher speeds and higher bearing temperatures have been made possible by the discovery of lubricants which are stable over a higher range of temperatures, like the silicones and polytetrafluorethylene and the use of bearings made of sintered metals like copper which can carry the liquid lubricant. Similarly, improvements in cutting liquids to remove the heat generated by the plastic deformation of metal by the machine tool and to diminish friction have added to the speed, the life of the tool and the quality of the machined surface.

Astronomical estimates have been made of the loss of metals, particularly iron and steel, by corrosion. With the increasing amounts of metal going into service and the growing use of thinner sections (for instance, in the steel pipelines that are carrying oil and natural gas many thousands of miles) protection against corrosion becomes increasingly important to guarantee the long life of these costly installations. Much progress has been made in methods of pre-treatment and in the application of protective coatings and wrappings, but the possibility always exists in a long pipeline of weak spots where corrosion may begin. Here, as with steel structures under water and with ships, the use of cathodic protection on an engineering scale, either by sacrificial anodes or by an impressed electromotive force, is adding greatly to the life of the structures and avoiding very costly failures and replacements. Cathodic protection was invented by Humphry Davy in 1825 but it is only now coming into general use on an engineering scale. He applied it to the protection of the copper hulls of warships, but the Admiralty discarded it because it encouraged the growth of barnacles. It is sad to remember that Davy left England under the strain of the disappointment and of public criticism and died abroad, seeking the consolation of a philosopher in travel. To-day his invention is a major factor in conserving engineering structures.

The Conservation of Human Labour

I have left to the last the engineer's conservation of human effort, both manual and mental, by mechanization, automatic control and electronic computers. In the race for productivity mechanization is the pace-maker. Recent figures from the United States show that the productivity per head has doubled with the doubling of the horse-power employed. And now a new factor is coming in, as automatic control not only replaces manpower and accelerates production but its products are of higher quality. Electronic devices are much quicker and more accurate than the human brain and can be used for an infinite variety of control purposes. And whereas the human senses can only deal with one operation at a time, an electronic system can regulate simultaneously the many interlocking controls required in a large plant. The nation-wide automatic dialling system of telephones in the United States is a good example. Then analogue computers can simulate complex operating problems and provide a short cut to the answer, and digital computers can solve in a few minutes differential equations which would otherwise require a prohibitive number of man-hours of work.

There is no need to dwell on the contribution of mechanization to the economies of the production line. Automatic control is another story. On the one hand, great progress has been made in the mathematical theory of control design which is directly applicable to the design of control equipment for systems in which the dynamic characteristics of the mechanisms are known. On the other hand, progress in instrumentation and in the technique of servo mechanisms has led to the widespread application of automatic control to machines and continuous processes which were not originally designed with this in view. If the maximum advantage is to be made of this new approach, its philosophy and theory must start in the design phase and be applied continuously. This entails both an appreciation of its possibilities by the designer and his co-operation with the control engineer who has specialized in control theory and instrumentation. A big educational problem is involved which is vital to Britain's industrial future especially now that full employment has been reached.

There is strong evidence from the United States and the Soviet Union of the much greater awareness of the urgency of this problem in both those countries. In the United States there are said to be close on 2 500 companies in the control business employing 8 000 graduate engineers who have specialized in this field, and there are 15 000 more in the user industries. Russia has concentrated her mathematical ability on the theory of automatic control and her numerous applications of it in industry show how effectively she has grasped its philosophy. In 1951 she was operating the first complete automatic production line of an aluminium-alloy piston from the ingot to the finished product, fully tested and examined, and in 1948 she had automatic plants making cylinder blocks and also agricultural machinery. Her automatic tests of surface finish are most effective and ingenious. Evidently her objective is high-quality machine production using a minimum of skilled personnel, thereby increasing her competitive position with the other great industrial powers of the world. This is the Russian engineer's contribution to conservation.

I do not wish to end this review of the engineer's achievements on a gloomy note so far as Britain is concerned, but in spite of the interest shown by a few firms, I must draw attention to the urgent need for a more active and general recognition of the future importance of control engineering in this country.

Conclusion

And now, what emerges from this patchwork survey of the engineer's massive contribution to conservation,

the need for which will increase with the growing population of the world and the depletion of its capital reserves? I said at the end of my James Forrest Lecture over 20 years ago "Progress to-day demands intense specialization on the one hand and on the other the widest outlook and knowledge of what is happening in other fields—intensive research and extensive application." And this is even truer now with the new techniques that have developed so rapidly since then. By and large, all are based on the application of research, and their complexities breed new kinds of specialists with the dangers that involves. The remedy is a synthesis of specialists, which indeed is the pattern of the combined operations these great engineering projects inevitably demand. This, I am sure, was the thought in Graham Clark's mind in seeking a better understanding between the Institutions and showing the need for their co-operation in the future. And this survey brings out another point: the need for an ever closer working with Nature. You cannot control Nature. She will always have her way, but with the more intimate understanding we are gaining of her ways a new partnership is possible with the great forces and resources that she embraces.

One final lesson emerges. In each generation there is a limit to what is possible, a limit imposed by the resources and skills that are available to mankind. In the future those resources and skills must be used to the best advantage, and with their unequal distribution among the countries of the world, some form of planning is ultimately inevitable, based on surveys of world needs and world resources. Only in that way can they be conserved for the use and convenience of man.

The Radio Section discuss

MATERIALS FOR VALVES

On the 21st March, 1955, Mr. R. O. Jenkins, Ph.D., opened a discussion with the above title before a meeting of the Radio Section. A summary of his remarks, and of the subsequent discussion, appear below.

DR. JENKINS began by recalling that valve making derived historically from lamp making and employs many materials originally used in lamps. Subsequent developments have demanded other materials, some used only in valves, others being more common materials produced to stringent specifications. This has resulted in two difficulties: first, the quantity of materials used only in valves is small and often barely justifies the setting up of production plant, and secondly, suppliers have a natural reluctance to working to very stringent specifications for common materials. In spite of these difficulties the art of valve making has advanced steadily and new or improved materials have contributed largely to this advance.

It is convenient to consider materials in valves as those used for three main purposes: (*a*) cathodes and heaters; (*b*) grids and other electrodes; (*c*) envelopes.

Cathodes and Heaters

It is thought unlikely that any new cathode will revolutionize valve making, and so the chief existing cathodes to be discussed are the oxide-coated type used mainly in receiving valves and the thoriated-tungsten type for transmitting valves.

Oxide cathodes consist of an alkaline-earth oxide layer on a core of nickel alloy, tungsten or occasionally platinum. The nickel must be made to a very stringent specification, and in this country has usually been O nickel, which is a low-sulphur-content pure commercial nickel containing about 0·1% magnesium as an activating agent. More recently smaller amounts of magnesium have been used to reduce barium evaporation. The growth of a resistive interface of barium silicate during life of a valve makes a nickel containing less than 0·02% silicon desirable for long-life valves. Such a nickel would probably be made by powder metallurgy and contain some tungsten and possibly aluminium as activating agents. Tungsten is tending to replace nickel alloys for low-current filamentary valves, to give freedom from filament breakage, and it is essential for ratings below about 50 mA.

Heaters for indirectly heated valves are usually made either of tungsten or molybdenum-tungsten alloy, but neither has proved completely satisfactory owing to brittleness caused by crystal growth during the high-temperature sintering of the alumina insulating coating. Alumina-doped tungsten is probably the best at the moment, but perhaps rhenium may in future prove to have a better safety factor. Brittleness is also the chief drawback of the thoriated-tungsten cathode now used even for the highest-power transmitting valves, and the manufacture of strip cathodes for u.h.f. valves will demand further development work by British suppliers.

Grids and other Electrodes

Receiving valve grids are usually made by winding a fine molybdenum or 5% manganese–nickel wire onto heavier side-rods. The choice of side-rod material is a compromise between strength, good thermal conductivity and low cost. Age-hardening chrome–copper seems the best compromise when good thermal conductivity is needed; otherwise nickel or nickel-plated iron is used. Molybdenum and manganese–nickel have drawbacks as winding wire; the former is costly, occasionally brittle and has a tendency to oxidize, while the latter is too weak for many grids. Perhaps a high-temperature nickel alloy might be the solution. For grid

wires below about 1 mil diameter, tungsten is the only suitable material. Transmitting-valve grids are usually made of molybdenum wire, which may be coated with platinum to suppress grid emission.

Receiving-valve anodes are made of nickel or nickel-plated iron, and they are carbonized when much heat must be dissipated. A cheaper material with high thermal emissivity is aluminium-clad iron, which, however, is not suitable for close-clearance rectifiers owing to its gas content. Glass-transmitting-valve anodes are usually made of molybdenum, often coated with zirconium powder. Graphite is also used, but has a high gas content, while the cost of tantalum usually precludes the use of this otherwise very suitable metal.

Envelopes

Receiving valves employ envelopes mainly of lime-soda glass, with the vacuum-tight connections made by copper-coated nickel–iron alloy (Dumet) or chrome–nickel–iron (No. 4) alloy wires sealed through lead glass. Higher-power glass valves generally have tungsten leads sealed into a borosilicate glass envelope. Cooled-anode transmitting valves increasingly use iron–nickel–cobalt alloy (under various trade names) sealed to an expansion-matching borosilicate glass.

Envelopes of vacuum-tight ceramics brazed to metal are being more and more used for v.h.f. and u.h.f. transmitting valves. A number of ceramic-metal combinations have been tried, but it now appears likely that alumina brazed to iron–nickel–cobalt alloy will probably be the best. Klystron and magnetron blocks are usually made of oxygen-free high-conductivity copper, and it is thought that vacuum melting and forging will eliminate the porosity which is sometimes experienced.

Miscellaneous Materials

Punched-mica insulators are still used to locate receiving-valve electrodes, in spite of mica's poor thermal stability and resistance to abrasion, for no satisfactory alternative has appeared. Most valves employ getters to absorb gas during life, and a barium film evaporated from a stable barium–aluminium alloy or a clad barium pellet is universal in receiving valves. In transmitting valves with thoriated-tungsten cathodes the usual getter is zirconium operating at an elevated temperature.

Discussion

Dr. Jenkins's introduction thus dealt with the most important materials in valves and it showed that valve development has always depended very much on special materials. Future advances will demand close co-operation between those engaged on fundamental materials research, the material's suppliers and the valve manufacturers.

In the subsequent discussion there was general agreement that most of the materials used in valve manufacture are capable of great improvement and it was several times suggested that idealized specifications should be prepared by the industry for use by manufacturers of materials. The view was expressed that such specifications would encourage the supply of satisfactory materials in large quantities.

It was recognized that in this country the use of low-silicon-content O nickel for cathode cores has prevented many of the difficulties experienced in the United States and on the Continent, where a high-silicon-content nickel has been used. In more recently developed types of valve even the low quantity of silicon present in O nickel makes it unacceptable for cathode cores, and a possible solution to the problem is the use of a 40% tungsten–nickel alloy. Among advantages claimed for this is that marked improvement in the ultimate strength can be obtained by a heat ageing process which does not affect the ductility of the alloy. Attention was also drawn to the low thermal conductivity of 40% tungsten–nickel alloy, which compares favourably with that of stainless steel—itself a poor conductor of heat.

The use of nitro-cellulose as a binder for cathode coatings was criticized, and it was shown that this could cause poisoning of the cathode, thus seriously curtailing the life of the valve. The use of alternative methods of cathode manufacture which did not call for this binder was advocated.

The problems associated with the manufacture of grids were touched upon. Difficulty has been experienced in preventing secondary emission from grids made of molybdenum and tungsten wires, and a method of overcoming this is to gold-plate the helix wire; but it is difficult to obtain non-porous plating, especially one which would still be satisfactory after the swaging of the grid to its support wires.

The use of alumina was mentioned as a possible material for supports and bases, although it was recognized that certain difficulties might arise in sealing glass to ceramic materials. It was, however, stated that the techniques in this field are rapidly improving, and it was thought possible that the use of alumina will be more widespread in the future, provided that firing techniques can be improved to reduce shrinkage losses. Good results were reported in the use of compression seals between ceramics and nickel, Kovar and nickel-iron alloys.

The practice of manufacturers of X-ray tubes of using impure materials where the impurities can be turned to advantage was mentioned; an example is the use of stainless steel in X-ray tubes, which is satisfactory, although it contains niobium, since this acts as a getter.

Some success has been reported abroad with the manufacture of envelope glasses for special purposes. In this connection the use in the United States of glass having a low surface-leakage resistance is claimed to eliminate difficulties associated with static charges on envelopes.

The use of conducting coatings on mica supports was touched upon, and it was suggested that research work in this field could be undertaken with great advantages.

Journal I.E.E., September 1955

The History of Electrical Engineering

4. MACHINERY FOR THE NEW LIGHT: PART 2

The third article in this series traced the evolution of the magneto-electric generator from its origin as a simple hand-driven device to its successful exploitation in light-house illumination. For clarity's sake the description omitted many developments which represented a departure from the main theme, but some of them—particularly the early dynamo-electric machines—were extremely important and are now reviewed here.

C. MACKECHNIE JARVIS, *Member*

An Improved Field System

As long ago as October, 1854, Sóren Hjorth, of Copenhagen, applied for provisional patent protection in this country for an electric generator far in advance of its time not only in respect of constructional detail but also on account of the principles cited by the applicant. Hjorth proposed to include within the compass of a single field-system both permanent magnets and self-excited electromagnets. The initial application was abandoned and Hjorth filed a new application and was granted Patent No. 806 on the 11th April, 1855, under the style of "An Improved Magneto-Electric Battery." The specification includes the following paragraph:

> The action of this battery is as follows: The permanent magnets acting on the armatures brought in succession between their poles induce a current in the coils of the armatures, which current, after having been caused by the commutator to flow in one direction, passes round the electro-magnets, charging the same and acting on the armatures. By the mutual action between the electro-magnets and the armatures an accelerating force is obtained, which in the result produces electricity greater in quantity and intensity than has heretofore been obtained by any similar means.

This remarkable machine, which anticipated Wilde, paved the way towards the discovery of the principle of self-excitation arising from remanent magnetism, but it does not appear to have been developed further at the time.

In November, 1858, J. H. Johnson, a patent agent of London, filed an application for a patent on behalf of "foreigners residing abroad," whose names were not disclosed, for "Improvements in the employment of electricity as a motive power." The application was subsequently abandoned, but the (provisional) specification was published in July, 1859, and in it the following statement appears:

> It is also proposed to employ the electro-magnets in obtaining induced electricity which supplies wholly or partially the electricity necessary for polarizing the electro-magnets, which electricity would otherwise be required to be obtained from batteries or other known sources.

There is no evidence that this machine was made, and nothing further seems to have developed from it.

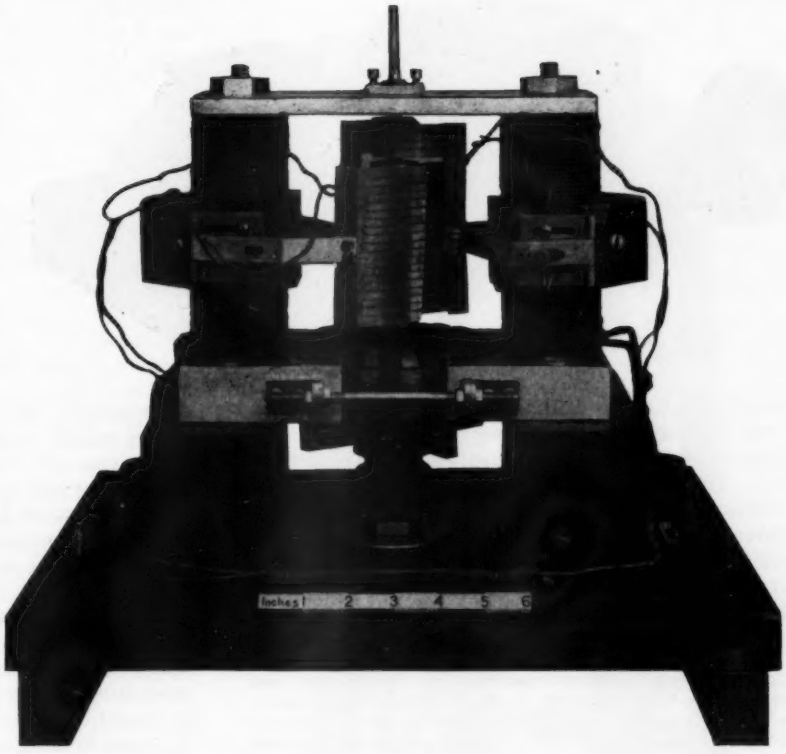
Developments in Armatures

The well-known Siemens "H" or shuttle armature was invented in Germany by Ernst Werner Siemens (1816–1892) and patented provisionally in this country in September, 1856, by his brother, C. W. Siemens, F.R.S. (1823–1883). It was the latter who in 1872 became the first President of The Institution, then known as the Society of Telegraph Engineers. The invention appears in an omnibus electric telegraph specification, where it forms part of a hand-driven magneto-electric machine. The patent application was abandoned, but in accordance with contemporary patent law and procedure the specification was published about six months later. The shuttle armature was used in small generators built by Siemens, Wilde (1861), Ladd (1866) and others. Its merit lay in its relatively small diameter and hence suitability for high-speed working, coupled with improved magnetic performance that resulted from the reduced air-gap and smaller field magnets which the small diameter made possible.

The next development in armature construction occurred in Italy, where Dr. Antonio Pacinotti (1841–1912), afterwards Professor of Physics at the University of Pisa in succession to his father, Luigi, was experimenting with electrical machines. Dr. Pacinotti, in 1860, constructed for the Museum of Technological Physics at the University a model of an electrical machine which, with the aid of an external battery, could be used to demonstrate the operation of an electric motor or of a separately excited generator. The machine is important, because it is generally considered that it was upon it that Gramme based his work. The first description of Pacinotti's invention appeared in 1864,[1] and there the designer referred to a "transversal electro-magnet." This consisted of a ring-pattern armature, comprising a core made in the form of a toothed iron wheel. Between the teeth on the wheel were wound sixteen separate coils joined in series to form a closed circuit. The junction of each pair of wires, sixteen in all, was connected to the commutator. The armature was suspended above a pair of electromagnets, substantially as shown in Fig. 1. Pacinotti's original machine was exhibited some years later, at the Paris Electrical Exhibition of 1881, and earned for its inventor an Award of Merit. He was elected to Honorary Membership of The Institution in 1902.

Passing of the Permanent-Magnet Field System

Meanwhile, in England, Dr. Henry Wilde (1833–1919), of Manchester, was conducting a series of significant experiments, initially in connection with telegraphic



1 *Pacinotti's separately excited electromagnetic machine, 1860, embodying the first toothed armature*

This is of ring construction with a multi-segment commutator.

[*Crown copyright. From an exhibit in the Science Museum, South Kensington.*]

projects. He took out a series of patents from 1861 onwards, the most important being No. 3006 of December, 1863, in which he describes the famous alternator, with its separate permanent-magnet exciter mounted above and driven from a common shaft.

In 1866, Wilde wrote a paper for the Royal Society, to which body it was communicated by Michael Faraday. The title of the paper was "Experimental Researches in Magnetism and Electricity, Part I." It was received on the 26th March, 1866, read on April 26th of the same year, and published in the *Proceedings*.[2] In it Wilde describes "a new and powerful generator of Dynamic Electricity." The paper contains the following significant paragraph:

> The Author directs attention to some new and paradoxical phenomena arising out of Faraday's important discovery of magneto-electric induction, the close consideration of which has resulted in the discovery of a means of producing dynamic electricity in quantities unobtainable by any apparatus hitherto constructed. He has found that an indefinitely small amount of dynamic electricity or of magnetism is capable of evolving an indefinitely large amount of dynamic electricity.

Reference is also made in the paper to Wilde's machines with the separate permanent-magnet exciter, some of which were constructed with commutators for producing direct current. How close Wilde was to the discovery of true self-excitation from remanent magnetism will be appreciated from the foregoing. The paper aroused considerable attention, both in this country and on the Continent. In the author's opinion, it must have come to the immediate notice of the brothers Siemens, one of whom, Charles, was already a Fellow of the Royal Society and the contributor of a paper printed in the same volume of the *Proceedings*.[3] That so important a contribution as Wilde's was immediately sent to Berlin there can be no doubt, for we know from Siemens's published memoirs that the Siemens family, and especially the brothers Charles and Werner, maintained a regular correspondence and also that Charles frequently took out patents in England for his brother's inventions.

In December, 1866, Cornelius and Samuel Alfred Varley (father and son) filed an application for a patent under the title "Improvements in the Means and Apparatus for Generating Electricity." The specification describes a self-excited electromagnetic generator in which the dependence of the field system upon the residual magnetism in building up the field is clearly recognized. The applicants explain that before using the apparatus "an electric current, passed through the coils of the electro-magnets, secures a small amount of permanent magnetism to their cores." The specification was not published until July, 1867, and this fact has tended to obscure the legitimate claims of S. A. Varley, the inventor, for a share in the credit for recognizing the fact that residual magnetism could provide the "indefinitely small amount of . . . magnetism" postulated by Wilde earlier in the same year.

2 *S. A. Varley's original self-excited dynamo, 1866*

The armature comprises two coils encased in a brass disc.

[*By courtesy of the Director of the Science Museum, South Kensington.*]

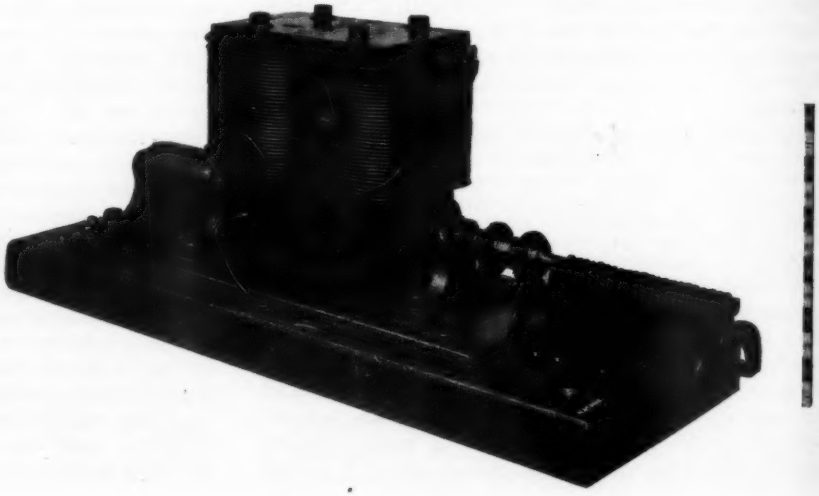
Simultaneously, in Berlin in the same month, Dr. Werner Siemens submitted a paper to the Berlin Academy of Sciences, before whom it was read on the 17th January, 1867.[4] The title in the English translation is "On the conversion of mechanical energy into electric current without permanent magnets." Siemens described a machine which operates on the same principle as that described by Varley, and in his paper acknowledged his indebtedness to Wilde in the following terms:

> Lately, Wilde of Birmingham has considerably increased the efficiency of magneto-electric machines by combining in one machine two magneto machines of my above described construction.* He provides the larger of these machines with an electro-magnet in the place of a steel magnet, and uses the other to effect continuous magnetisation of this electro-magnet. It can easily be perceived that by means of this combination Wilde has considerably diminished the above defects of the steel magnet machine. Setting aside the inconvenience of employing two inductors at the same time to produce one current, his apparatus is dependent on the uncertain performance of the steel magnet.

It is difficult to believe that Siemens seriously considered that the residual magnetism in his soft iron electromagnet was more certain than the magnetism in a steel magnet although none would deny the greater convenience of the arrangement. Werner Siemens's Berlin paper was not published for several months, and in the meantime his conclusions were embodied in a paper communicated to the Royal Society of London[5] on the 14th February, 1867, by his brother Charles, who exhibited with it a hand-driven generator.

At the same meeting, another pioneer, Professor (afterwards Sir Charles) Wheatstone, F.R.S. (1802–1875) read a paper on the same subject,[6] and also exhibited a hand-driven generator similar to that of Siemens except in respect of the winding details. Wilde was present at this meeting and gave an account of it to the Manchester Literary and Philosophical Society five days later, in reply to a question "whether any member was acquainted with particulars of a remarkable discovery in connection with the conversion of dynamical into electrical force by M. Siemens and Dr. Wheatstone, a brief notice of which appeared in the *Athenaeum* of February 16th."[7] Wilde described the machines he had seen and commented "that having himself sometime ago made similar experiments to Siemens and Wheatstone, he came to the

* Siemens here refers to the shuttle armature which he had introduced in 1856.



3 *Self-excited generator exhibited by C. W. Siemens at a meeting of the Royal Society in London on the 14th February, 1867*

This machine employs a shuttle, or "H," armature.

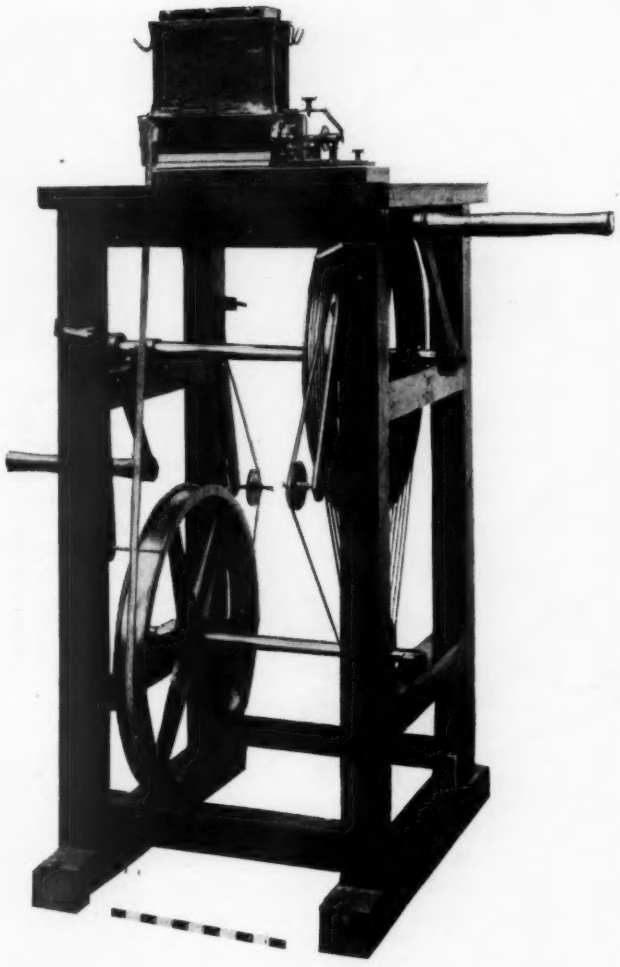
[*By courtesy of the Director of the Science Museum, South Kensington.*]

conclusion that in the present state of our electrical knowledge the difficulty of utilizing current after it had passed through the coils of the electro-magnet when excited by intermittent currents was insuperable." He was of the opinion that although the results obtained were undoubtedly very interesting from a scientific point of view, the practical results were inferior to those of separate excitation.

In interpreting this statement, it must be remembered that machines of this period with Siemens "H" armatures were provided with two-segment commutators, and thus delivered a pulsating unidirectional current. The first electromagnetic generators were of the series-wound pattern, and the impedance of the field windings, especially at the higher speeds, would have been considerable. This difficulty was inseparable from the shuttle armature, and it is therefore not surprising to find that as late as 1873 the Siemens brothers were following the practice of Wilde in using a separate exciter for the field of the main generator. Such a combination was shown at the Vienna Exhibition of that year, and this suggests that only in matters of publicity was Wilde at this time behind his contemporaries on the Continent.

Another matter which Wilde disclosed to the Manchester meeting was that he had received a letter written on the 9th November, 1866, by an American correspondent who indicated that he, too, had discovered the principle of self-excitation without the use of permanent magnets. The letter was from Moses G. Farmer, of Salem, Massachusetts, a name well known among the early electrical manufacturers in the United States. The relevant passage reads as follows: "I have built a small machine in which a current from the thermo battery excites the electro-magnet of your machine to start it, and after the machine is in action, a branch from the current of the magneto (i.e. armature) passes through its own electromagnet, and this supplies the magnetism required." The reference to a branch current indicated that the generator was, in effect, shunt-wound, and that it would thus appear to anticipate the use of the shunt connection by Wheatstone. Wilde's paper to the Royal Society in April, 1866, was primarily responsible for stimulating in the minds of others a train of thought which led to the almost simultaneous realization of the principle of self-excitation by three or four independent inventors.

In March, 1867, there occurred an event which was to have great significance nearly forty years later, when credit for the invention of the dynamo was claimed and disputed. This was the publication by Charles Brooke, F.R.S. (1804–1879), of a paper[8] before the Royal Society, in which the compound term "dynamo-electric" was first employed. Brooke used it in the generic sense to denote apparatus capable of converting mechanical into electrical energy and he used the term "electro-dynamic" conversely in relation to the action of electric motors. In his paper Brooke quoted as examples of dynamo-electric machines the glass-plate machines of Holtz "and the



4 *Wheatstone's self-excited generator exhibited at a meeting of the Royal Society on the 14th February, 1867*

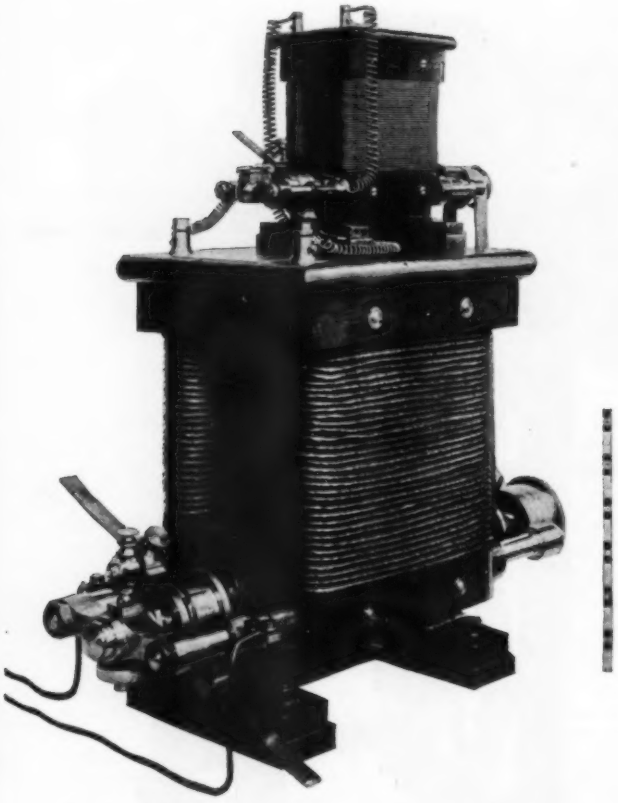
This machine has a shuttle armature.

[*Crown copyright. From an exhibit in the Science Museum, South Kensington.*]

cognate machines of Wilde, Wheatstone, Siemens and Ladd."

For obvious reasons self-excited generators tended to be popular, and became known as dynamo-electric machines, the term being shortened by common consent to dynamo. Such machines were primarily suitable for producing direct current, and thus the expression became associated in a specific sense with d.c. generators. Subsequent writers of the period used the expression to distinguish generators with wound field systems from those of permanent-magnet construction, which were called magneto-electric machines.

The magnet cores of the early dynamos were not



5 *Wilde's famous combination of an electromagnetic generator with magneto-electric exciter, 1867*

Both armatures are of the Siemens "H" type.

[*Crown copyright. From an exhibit in the Science Museum, South Kensington.*]

laminated, and since the frequency of the current pulsations often amounted to upwards of 60 per second, it is not surprising that heating constituted a major problem and limited the period of continuous operation from cold to a maximum of about three hours. A number of Wilde's dynamos were purchased by Elkington & Co., of Birmingham, for electroplating purposes. According to Wilde, Mr. Charles E. Ryder, the factory manager, devised a method of water cooling for the field magnets and fed the heated water to a boiler hot-well! A water cooling system was also used by Siemens and Halske on one of the dynamos exhibited in Vienna in 1873.

The dynamo of William Ladd, to which reference has frequently been made, was a composite machine with two separate shuttle armatures revolving in a common magnet system. One armature supplied the excitation for the field magnet whilst the second, and larger, fed the external circuit. This machine was constructed in 1867 and exhibited at the Paris Exhibition of that year, where it was the subject of an award.

The Gramme Ring and the Drum Armature

It is generally considered that the credit for producing the first practical dynamo yielding a truly continuous current is due to Zénobie Théophile Gramme (1826–1901). Gramme was a native of Belgium, but most of his work was carried out in Paris, where in 1870 he produced his first generator. He developed a ring armature using soft iron wire, an arrangement which had previously been advocated by Joseph Henry (1797–1878) for the construction of the magnets of telegraph relays. In principle, Gramme's armature followed that of Pacinotti; the winding was continuous, and was tapped at intervals for connection to a multi-segment commutator. During the winding of the core, the iron wire was caused to pass through a bath of bituminous compound, which insulated the individual strands and thus considerably reduced eddy currents.

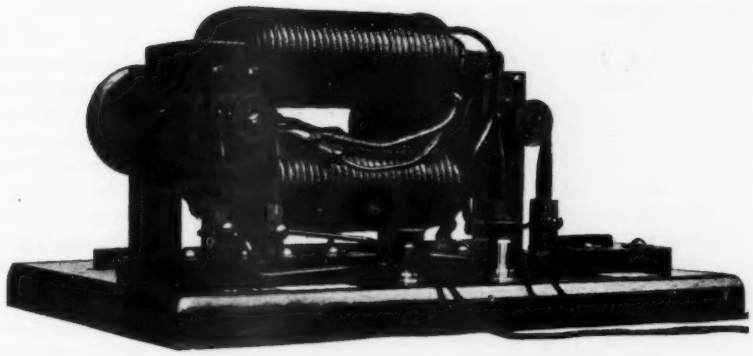
The first Gramme machine was exhibited before the Paris Académie des Sciences in July, 1871. It formed the subject of several patents in this country, the first of which was No. 917 of 1870, and there were others taken out in the name of one of Gramme's Paris associates, Hippolyte Fontaine. Within a short time, the Gramme organization was manufacturing dynamos in large numbers in Paris, and similar machines were constructed under licence in a number of countries, including England.

In 1873 a Gramme dynamo was brought from Paris to London in connection with lighting trials in the upper lantern of the clock-tower at Westminster, where the electric light was in competition with Wigham's improved gas light. From this time forward, numerous firms entered the field with variations on the Gramme theme, and among the best known in this country were those of Bürgin, Brush and Wallace Farmer.

In the United States the Gramme dynamo was made by the Fuller Electrical Company, and in England by the British Telegraph Manufactory under the direction of Robert Henry Sabine (1837–1884), one of the eight founder members of the Society of Telegraph Engineers. Sabine, who was a son-in-law of Sir Charles Wheatstone, had worked with C. W. Siemens in London and Werner Siemens in Berlin, and also with Latimer Clark and Wheatstone.

The Bürgin dynamo originated with Emile Bürgin of Basle, Switzerland, and consisted of a series of four or more squares of iron wire, each carrying four coils (one per side) wound in the conventional ring manner. The machine, which was the subject of several English patents from 1875 onwards, was a great improvement on the early Gramme dynamos, in that the "rings" were spaced to produce a machine greater longitudinally than the Gramme, the coils being relatively small in diameter and therefore less subject to heating in operation.

An English pioneer, Col. Rookes Evelyn Bell Crompton, F.R.S. (1845–1940), saw the machine about 1880, and perceived in it the essence of a successful dynamo. In Crompton's hands the armature core was changed in shape from square to hexagonal and provided with six



6 *Ladd's twin-armature dynamo with a common field system, 1867*

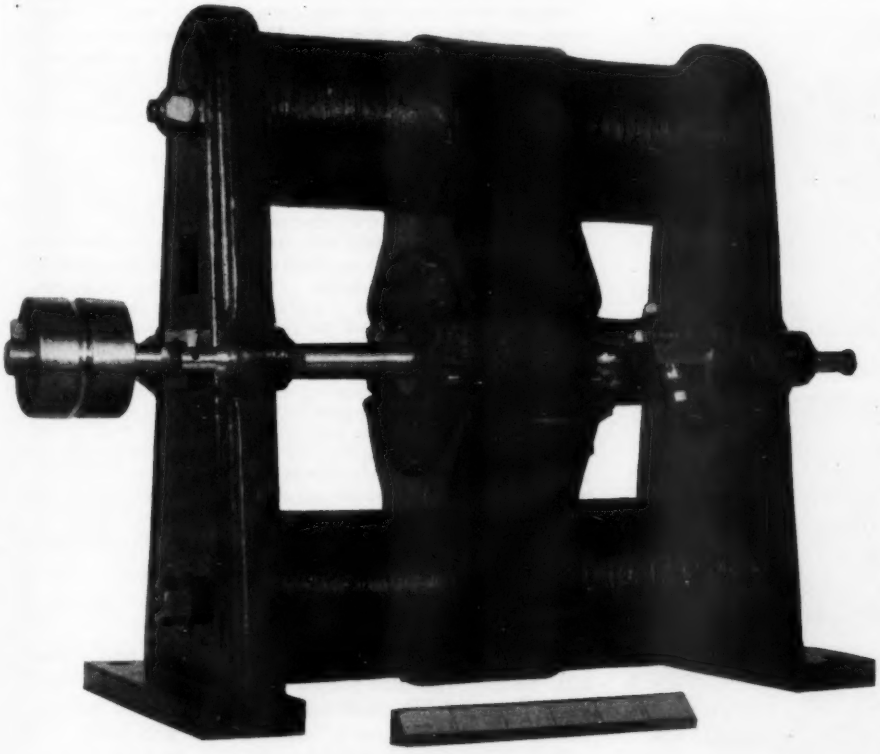
The machine is self-exciting, the first armature acting as an exciter for the field system of the second.

[*Crown copyright. From an exhibit in the Science Museum, South Kensington.*]

coils per ring. The number of rings per armature was increased to ten. The rings were supported on the spindle by means of a spoked frame, and each successive ring was displaced angularly from its predecessor by an amount equal to one-sixtieth of the circumference. Although the armature of the Crompton–Bürgin dynamo possessed the great advantage of good ventilation, the induction between neighbouring rings introduced difficulties, and after a few years the arrangement was abandoned in favour of a modified Gramme ring.

Professor Gisbert Kapp (1852–1922) was for a time Chief Engineer in the Crompton works at Chelmsford and joint patentee with Crompton in 1882 of the compound field winding for "maintaining a constant electromotive force at the terminals of dynamo machines." It is generally conceded that the compound winding was first used about 1878–79 by the American pioneer electrician Charles Francis Brush (1849–1929). Brush added a shunt winding which he called a "teazer" to electroplating generators in order positively to prevent reversal of the direction of current through the baths.

The success of the Gramme ring was viewed with concern in Berlin, but it was not long before an answer was found in the form of the drum armature invented by Friedrich von Hefner Alteneck, chief designer to Siemens and Halske, in 1872 and patented in England in the following year. In the first machines of this class the armatures were drums of wood with windings held in position by pegs driven into the surface of the wood cylinder. Subsequently, the wooden drums were overwound with iron wire, on top of which the windings were located as before.



7 *An early Gramme dynamo with ring armature, 1870–71*

[*By courtesy of the Director of the Science Museum, South Kensington.*]

Ten years later, in January, 1883, Dr. Paget Higgs, of the Higgs Electric Light and Power Co., wrote in *The Electrician*:[9] "At the present stage of electric work, however, I should be surprised to see any maker putting iron into his armature, where that armature has to carry over 100 amperes, not so much on account of the loss of efficiency in working as for the reason that the machine must become very cumbrous and costly to make."

It is unnecessary to point out that the drum armature possesses the advantage that the greater part of the conductor is usefully employed, unlike the Gramme ring, where the inside portion of every turn is ineffective. Many years elapsed before the best combinations of windings and commutator segments were evolved, but the invention has proved of lasting value in the realm of dynamo design. The early drum armatures were not by any means free from troubles, among which were excessive sparking, due to the unsymmetrical arrangement of the windings first used by von Hefner Alteneck, a tendency to be unduly sensitive to fluctuating loads (which again caused sparking at the brushes), and heating of the armature windings, which rose in temperature much more rapidly than the field windings.

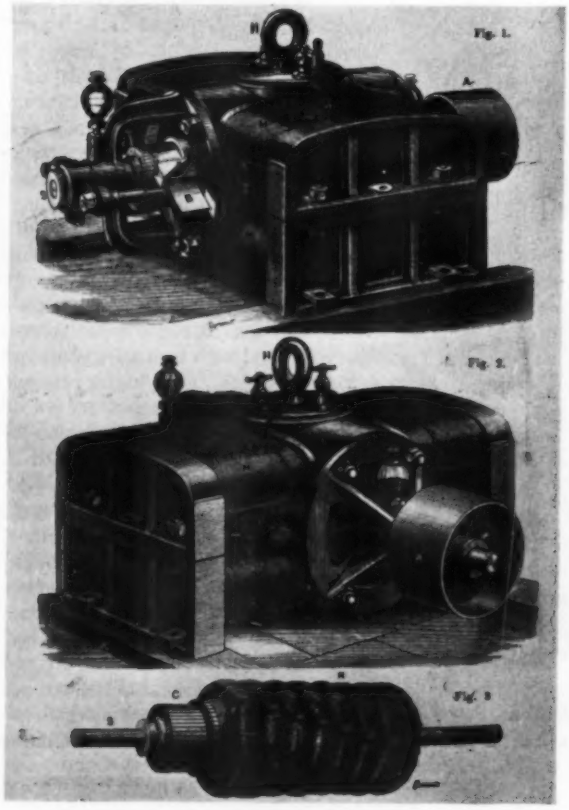
One of the most successful of the early American companies was that founded by Brush. This played an active part in the development of electric lighting and public supply, both of which subjects will be dealt with in subsequent articles in this series. Brush's first machines were produced in 1877–78, and his first English patent is that of 1878, which relates to a dynamo machine with a ring armature of special design. A branch of the Company, known as the Anglo-American Brush Electric Light Corporation, was floated in this country about 1882 and was followed by provincial subsidiaries.

The following excerpt from an editorial article on "The Electric Light" which appeared in *Engineering* on the 19th October, 1877, is of considerable interest as reflecting informed contemporary opinion. The article was unsigned but was almost certainly written by James Dredge.

> Gramme produced a machine, which at the time (viz. 1873), was the most powerful in existence as well as the most economical dynamo-electric machine, and bid fair to revolutionise the whole science of illumination and to stand unrivalled as a producer of electricity. It was said and believed that the Gramme machine had solved the long-sought problem of how to produce cheap electricity.
>
> At the Loan Collection (i.e. Exhibition) at South Kensington held in 1876, the public had an opportunity of seeing machines of Société Alliance, M. Gramme and Messrs. Siemens at work, and all must have been struck by the small size of the Siemens machine. Light from the Siemens and Gramme machines was apparently of the same intensity, but the Siemens machine was a quarter of the size of Gramme's and about one-eighth of the weight.
>
> In consequence of this Exhibition, the Corporation of Trinity House invited the makers of dynamos to a competitive trial. The English representatives of Gramme, Siemens and Wilde accepted. The French proprietors of the Gramme dynamo refused to compete. Conditions of the trial were laid down by Trinity House. Wilde would not agree, and withdrew. These trials were carried out under the direction of Professor Tyndall, F.R.S., . . . at the South Foreland in 1877. The upper and lower towers were each equipped with Gramme and Siemens arc lights, and every reasonable combination could be obtained. These trials went unmistakably in favour of the Siemens machine.
>
> . . . There can be no doubt with apparatus producing so great an intensity of light, and at so small a cost that the time is close at hand, if it has not already come, when ocean-going steamers will have to carry electric lights for the prevention of collisions at night, for discovering other vessels, rocks, shoal water, or land from two to three miles ahead, and for facilitating the operation of taking in or discharging cargo at night. . . . For ships of war, the electric light is of still greater value as a protection against the attacks of torpedo boats at night, and for this purpose, is being fitted to several of the new ships in Her Majesty's Navy, and it is employed for this purpose in the ships of the French, Russian and Spanish navies.
>
> . . . We believe there is a great future for electrical illumination, and as fresh improvements, and new invention will arise, it will become of more general application. Perhaps the time is not far distant when electricity will be, as an illuminating agent, as familiar to the public as gas is now, though we must confess that we do not consider the subject has advanced so far as to justify the depression in gas shares with which a recent ingenious invention, known as the electric candle, was lately accompanied.

8 *Crompton's improved Bürgin dynamo, 1881–82, employing multiple hexagonal armature cores of ring construction*

[*By courtesy of Crompton Parkinson, Ltd.*]



The Inventor of the "Dynamo"

In later years, after the events outlined above had passed into history, the part played by Wilde, who had outlived most of his contemporaries, tended to become obscured and frequently overlooked, and this was undoubtedly responsible for the somewhat uncompromising attitude he displayed during the early years of the present century.

The first incident arose when Wilde was awarded the Albert Medal of the Society of Arts in June, 1900. The award was for "the discovery and practical demonstration of the indefinite increase of the magnetic and electric forces from quantities indefinitely small." The citation proceeded: "The Council also recognizes the fact that your discovery is the principle on which the modern dynamo is based, and they believe that its value may be fitly recognized by the award they have now made to you." Wilde objected strenuously to the terms of the award, on the ground that they did not specifically state that he was the inventor of the dynamo-electric machine. Through his solicitors, he sought to compel the Society to withhold publication of the award until the terms could be agreed, but, notwithstanding the fact that such a situation had arisen, the Society released a statement, which appeared in the Press, and a somewhat disagreeable situation resulted. The Society, on the advice of its referees, declined to meet Wilde's wishes in respect of his claim to have invented the dynamo, and, as a compromise, modified the terms of the award to include a reference to the electric searchlight and electrodeposition of metals, with which he was prominently associated. Wilde was not prepared to agree, and the incident was closed when the Society created a precedent by sending the gold medal through the post. On previous occasions recipients had been presented with the medal by the Prince of Wales, afterwards King Edward VII. Wilde thereupon published the correspondence[10] and presented his Albert Medal to The Institution.

About this time, Murray's "New English Dictionary on Historical Principles" was in course of publication, and the editor invoked the aid of Professor S. P. Thompson, F.R.S., in respect of matters concerning electricity and magnetism.[11] On Thompson's authority, the printed version of the dictionary stated that the first use of the term "dynamo-electric" was by Werner Siemens in his paper before the Berlin Academy in January, 1867, in connection with a machine he had invented. Wilde again entered an objection, and threatened an injunction against the printers and the editor. He raised further objections to statements of a rather general nature in Thompson's "Michael Faraday" and in the same author's "Dynamo-Electric Machinery," a new edition of which was then known to be in course of preparation.

In 1902, the electrical world was startled by the sensational news that a writ for libel had been issued by Dr. Wilde against Professor Thompson in respect of statements appearing in the earlier editions of Thompson's books. Wilde claimed, substantially, that he was the inventor of the machine commonly known as the dynamo, that the term "dynamo-electric" coined by Brooke referred expressly to his machine, and further that any statements to the contrary, and in particular those which sought to give credit elsewhere, ran counter to fact and were damaging to his reputation.

Thompson was advised to enter a demurrer pleading that the Statement of Claim in the action should be set aside on the ground that it showed no cause for proceedings and was vexatious. These preliminary proceedings went in favour of Thompson on purely legal grounds, and the action was dismissed. The judgment was upheld in the Court of Appeal, and there the matter might have ended, but for the fact that Thompson published in *The Electrician*[12] a long letter explaining his position. Wilde, through his solicitors, replied, and the correspondence continued for some weeks until Thompson withdrew.

9 *Dr. Henry Wilde, F.R.S. (1833–1919)*

Among many other benefactions, Dr. Wilde founded the Wilde Benevolent Trust Fund of The Institution. This portrait taken at the age of 56 is reproduced by courtesy of the Manchester Literary and Philosophical Society. It is probably the only surviving likeness.

Nothing that transpired can affect the high reputations which the disputants enjoyed, and The Institution honours the memory of both. Thompson, a D.Sc., was President for the year 1899, and Wilde, also an Hon. D.Sc. and Hon. D.C.L., was an Honorary Member of The Institution from 1898 until his death in 1919. Both were Fellows of the Royal Society. Obviously, memories on both sides were at fault, but as a result of the correspondence Wilde's solicitors published an earlier letter[13] from Thompson to Wilde concerning the position of Siemens, which otherwise might never have been disclosed. Thompson had written: "In making the former statement that this word (dynamo-electric) was first used by Werner Siemens in his paper at the Berlin Academy of Science, I was misled by Siemens' own subsequent allegation that he had done so. As, however, in the printed paper the word does not appear, and as (on enquiry in Berlin) no one remembers that he did so, when communicating the paper, it is clear that his statement cannot be accepted as historic."

Wilde's pioneer work on the marine searchlight commenced in the 1870's. By 1876 he had persuaded

the Admiralty to permit full-scale trials, which were successful, as the following minute on "Wilde's Electromagnetic Light" shows: "Rear Admiral Sir F. Beauchamp Seymour, K.C.B., to the Lords Commissioners of the Admiralty November 10th 1876: 'The electro-magnetic machine fitted to the Minotaur by Messrs. Wilde & Co. has now been in use for seven months and having thoroughly tried it under all circumstances of wind and weather, including fog, I am enabled to give my testimony to its great value.' "

References

1 *Il Nuovo Cimento*, 1864.
2 *Proceedings of the Royal Society*, 1866, 15, p. 107.
3 *Ibid.*, p. 71.
4 *Monatsberichte Akademie der Wissenschaften*, Berlin, 1867, p. 56.
5 *Proceedings of the Royal Society*, 1867, 15, p. 367.
6 *Ibid.*, p. 369.
7 *Proceedings of the Manchester Literary and Philosophical Society*, 1866-67, 6, p. 103.
8 *Proceedings of the Royal Society*, 1867, 15, p. 408.
9 *The Electrician*, 1883, 10, p. 179.
10 "Correspondence in the Matter of the Society of Arts and Henry Wilde, D.Sc., F.R.S." (Manchester, 1900).
11 THOMPSON, JANE S. and HELEN G.: "Silvanus Phillips Thompson, His Life and Letters" (T. Fisher Unwin, 1920), p. 99.
12 *The Electrician*, 1903, 52, p. 60.
13 *Ibid.*, p. 177.

The Measurements Section discuss

SURGE DIVERTERS

On the 19th April, 1955, Mr. R. Davis, M.Sc., Member, opened a discussion on "The Measurement of Impulse Voltages and Currents with special reference to the Testing of Surge Diverters" at a meeting of the Measurements Section. His remarks, and the subsequent discussion, are summarized below.

MR. DAVIS began by defining a surge diverter as a 2-terminal device usually located between a high-voltage line and earth close to equipment which may be exposed to high-voltage surges, of atmospheric origin or arising from switching operations. In the form most commonly used it consists of a number of silicon-carbide discs in series, one end of the column being connected to one terminal and to earth, and the other via an isolating gap to the second terminal, which is connected to the line. The discs and gap structure are housed in a weatherproof porcelain shield. Modification to this sample structural scheme may include the use of a multi-electrode gap structure and the addition of impedances in parallel with individual gaps to secure uniform distribution of the normal operating voltage across them. The function of the isolating gap is to ensure that under normal operating conditions the energy dissipated in the conducting column is a minimum; when a voltage of predetermined minimum amplitude is applied to the terminals, breakdown of the gap should occur and the column should provide a low-impedance path to earth; when the current has fallen to a low value it is interrupted through deionization of the gap, and the normal operating condition of the surge diverter should be restored. The low-impedance path to earth is provided by the silicon carbide, the current through which increases as the third or fourth power of the voltage across it.

Impulse tests on surge diverters should provide evidence that they will restrict the over-voltage appearing at the terminals of protected equipment to a predetermined value; they provide no evidence of the adequacy of weatherproofing or of satisfactory performance under normal operating conditions.

To assess the adequacy of the diverter as a protective device, three types of test have been used, namely

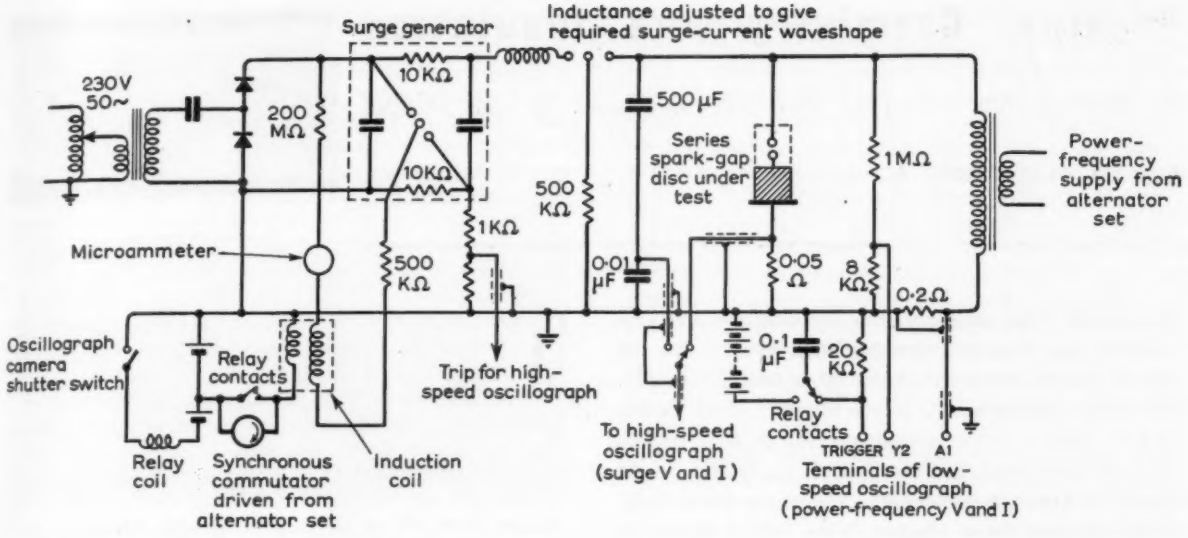
(*a*) The measurement of the breakdown voltage of the isolating gap.

(*b*) The measurement of the maximum voltage across the diverter when the isolating gap has broken down and the device is passing a surge current of prescribed shape and amplitude.

(*c*) The simultaneous application of a power-frequency and impulse voltage—the operating-duty test.

Test (*a*) is made first at a voltage provided by the normal impulse generator, which causes breakdown at or beyond the peak, and secondly at a voltage and wavefront steepness high enough to cause breakdown on the wavefront. The breakdown voltage is usually measured with a cathode-ray oscillograph in association with a voltage divider. The oscillograph method is probably essential for the wavefront breakdown test and for measurement accurate to a few per cent a voltage divider with a constant ratio over a wide frequency band is necessary. This performance can be obtained with both capacitive and resistive dividers, the latter being preferably of the shielded type. Special precautions are necessary to ensure that the potential points are taken as close as possible to the diverter terminal, so that the voltage in an impedance carrying a large current is not measured.

In addition to voltage measurements, test (*b*) requires surge-current measurements and the provision of special circuits to produce the required current waves. The current is calculated from the voltage drop across a non-inductive resistor in series with the surge diverter. The resistor should be capable of passing the prescribed current without appreciable change in value through heating. The time-constant requirements are not excessively stringent, since the current waveshape is either a 5/10 or 10/20 microsec wave or a flat-topped wave. Care must be taken to ensure that the attainment of a reasonably low self-inductance in the measuring resistor is not vitiated by inattention to the need for a low mutual inductance between the voltage and current circuits of the resistor, since mutual inductance has in the past led to gross overestimation of large transient currents. For the production of current waves of shape $n/2n$, e.g. half sine waves, a capacitance C charged to a voltage V is discharged through the surge diverter via an inductance L. To secure the required amplitude and value of n the



1 *Circuit for making the operating-duty test*

variables available are C, V and L. The presence of the surge diverter ensures that any overshoot beyond the first zero after the start of the wave is small. Sometimes a long-duration flat-topped current wave is prescribed, and to generate such a wave a circuit incorporating an artificial line is required. This seems an unnecessary complication in a test designed to demonstrate the energy-absorption properties of the conducting column when the same end could be achieved by the much more easily generated half sine wave.

The operating-duty test designed to demonstrate the deionizing property of the isolating gap calls for no additional special surge-testing techniques. The test involves the sumultaneous application of a surge and a power-frequency voltage, the surge being arranged to occur at a particular point in the power-frequency cycle. The circuit arrangements (Fig. 1) are somewhat complicated, but the carrying out of the test poses no special problems.

The conclusion of Mr. Davis's survey was that the testing of surge diverters calls for no special refinements of surge-testing technique.

In the subsequent discussion no speaker reported unsurmountable difficulties in testing, but instances were given of the gross errors introduced by spurious induction between heavy-current sections in badly planned test circuits. A speaker suggested that such effects can be unmasked by taking current measurements, first with one resistor and then with a second having identical proportions but made of material of different resistivity.

Several speakers observed that impressed voltage waves of the same apparent shape and steepness would indicate breakdown voltages differing by 10% because of detailed irregularities in the waveshapes. A speaker suggested that in this respect a square wave promoted consistency, and he gave details of a circuit which provides such pulses in a simple manner and in a choice of lengths.

Another speaker recalled that a pulse of low amplitude but of length extending beyond the span of the visual display could by this persistence produce destructive heating in a diverter element.

It was noted that the full benefits of insulation co-ordination in a power system can be obtained only if the breakdown voltages of the diverters were dependable.

The growing use of surge diverters to accommodate switching surges means that the appropriate breakdown voltages are lower and require closer control than was accepted when only lightning surges were in question.

Japanese appraisals of the tests for the short-circuit-capacity of diverters were described; for realistic tests the recommended optimum short-circuit capacity of the testing generator was given as one-third of that of the system for which the diverter was intended.

In operating-duty tests the British practice is to impose a positive surge on the positive wavefront of the power-frequency cycle, but speakers had tried other procedures. The variety of follow currents indicates the degrees of stress and severity obtainable in tests and it was remarked that the most onerous condition should be selected.

Subsequently this speaker and others referred to checks on the condition of diverters conducted perhaps after delivery. Whereas the gap is easily tested, a full-duty proof of the non-linear element is a major undertaking. One suggestion was to test with a current of less than the prospective value, but other speakers objected that this would release an unrealistically small amount of energy in the semi-conductive material.

Most speakers mentioned earthing as a matter of occasional difficulty in tests; the majority favoured a single earth, usually at the foot of the surge generator.

Journal I.E.E., September 1955

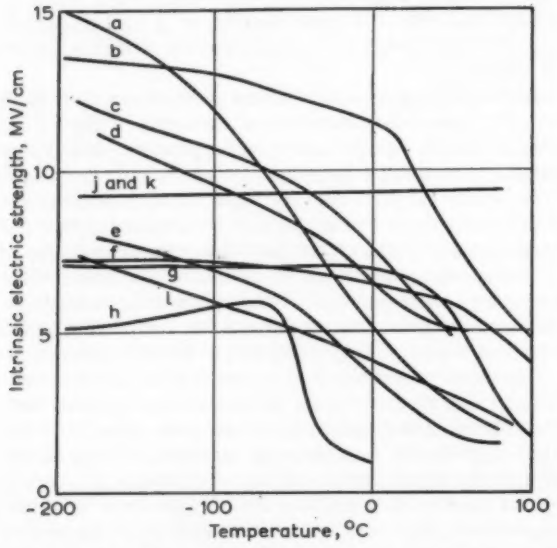
Physics, Chemistry and Insulation

A Short Review based on Two Recent Books by von Hippel

By C. G. GARTON, *Member*

Microscopic cracks in vitreous enamel, recorded by leakage current [*Church*]

Publication within six years of no less than five books on dielectric theory and electrical insulation indicates renewed interest in a subject much neglected by engineers. Recently, two books by Professor A. R. von Hippel,* of the famous M.I.T. Laboratory for Insulation Research, have made a welcome appearance, and here Mr. C. G. Garton, of the Electrical Research Association, reviews the books themselves and some recent progress in the field of dielectrics.



1 *Variation of intrinsic electric strength with temperature for various materials*

(*a*) Polyvinyl alcohol.
(*b*) Polymethyl methacrylate.
(*c*) Polyvinyl chloride-acetate.
(*d*) Chlorinated polythene (55% chlorine).
(*e*) Clear-baking oil varnish.
(*f*) Polystyrene.
(*g*) Polythene.
(*h*) Polyisobutylene.
(*j*) Ruby Muscovite mica.
(*k*) Borosilicate glass.
(*l*) Typical varnishes.

THE technique of insulation advances mainly by two routes. On the one hand, detailed analysis of mechanisms of failure may suggest modified designs which avoid, or inhibit, some essential factor in the mechanism. The alternative is invention and development of more resistant materials.

While these questions may be outside the scope of "Dielectrics and Waves," which is essentially a lucid and elegant textbook of physics, "Dielectric Materials and Applications" might well have covered both lines of work. Following, perhaps, too literal an interpretation of its title, the book deals with the stable properties of dielectrics and their resultant uses, almost to the exclusion of those mechanisms of deterioration which limit the application of a given material. The reader learns nothing, for example, of recent work which has so successfully elucidated the electrical breakdown of solids. Intrinsic electric strength is not mentioned, except in the form of a single curve for polythene in which no distinction is made from the ordinary electric strength, and

2 *The discharge detector* [*Mole*]

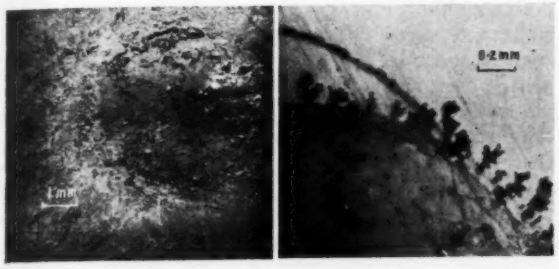
Top left: Oscillograph display and calibrating unit.
Top right: H.T. supply control (not part of the detector).
Centre foreground: Capacitor under test.
Right foreground: Tuning selector, to match capacitance under test.
(The tall cylindrical objects are h.t. interference-suppression and by-pass capacitors.)

* **DIELECTRICS AND WAVES**, by A. R. VON HIPPEL. Chapman and Hall. 280 pp. £6 8*s*.
DIELECTRIC MATERIALS AND APPLICATIONS. Edited by A. R. VON HIPPEL. Chapman and Hall. 425 pp. £7.

The other books referred to are:
FRÖHLICH, H.: "Theory of Dielectrics" (Clarendon Press, 1949).
WHITEHEAD, S.: "Dielectric Breakdown of Solids" (Clarendon Press, 1951).
JACKSON, WILLIS (Editor): "The Insulation of Electrical Equipment" (Chapman and Hall, 1954).

the subject of damage by discharges is dismissed in one half-page.

Much more than this is known. (See, for example, Whitehead's book referred to in the footnote on this page.) Prolonged work, much of it in Britain, has analysed breakdown into several distinct mechanisms. About twenty years ago it was shown that electric strength depends upon discharges in voids or interstices,



a b

3 *Examples of erosion by discharges* [*Parkman*]

(*a*) Surface of a moulded phenolic disc (nylon and cellulose filler) after 13 h under 5·7 times the discharge-inception voltage, at 500 c/s.
(*b*) Eroded dendritic pits in moulded nylon (light area) due to discharges within a cavity (dark area).

or on the surface of the material, and that if these are suppressed an intrinsic strength appears, in sufficiently homogeneous materials, with values about ten times greater than were previously accepted. Results, obtained with much experimental difficulty, for a dozen or so materials,* are shown in Fig. 1. These stresses, averaging roughly 5×10^6 volts/cm (12 kV/mil) are much higher than can yet be used in practice, but they demonstrate that all other types of breakdown are secondary, and so, with enough ingenuity, can be circumvented.

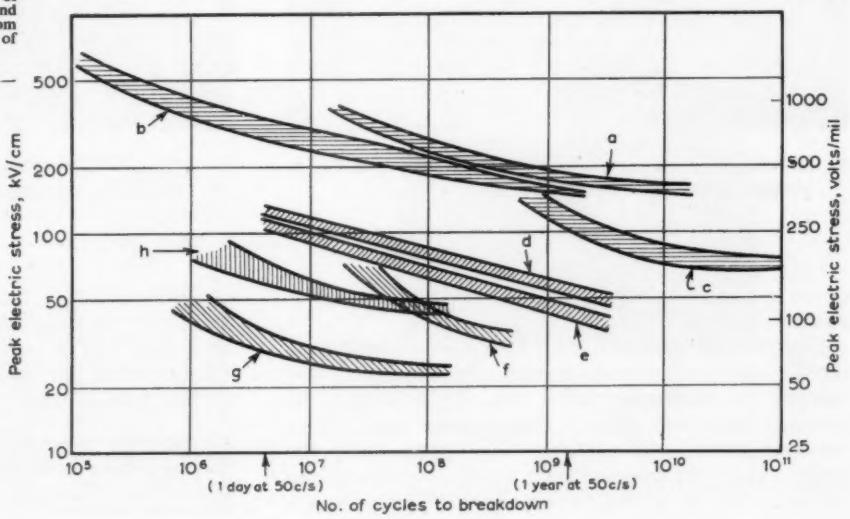
* The abrupt transitions in curves *g* and *h* of Fig. 1, have recently been shown by K. M. Stark and the author to be spurious and to arise from mechanical deformation. (A letter is in course of publication elsewhere.)

Erosion by discharges, long vaguely recognized, has in recent years been studied quantitatively. Little on this subject appears in "Dielectric Materials and Applications," and the contributors do not sufficiently stress its importance in modern design. A commercial instrument for the detection and measurement of a.c. discharges[1] has been developed in this country by the Electrical Research Association, and is shown in Fig. 2.

Insulation exposed to discharges of low intensity is slowly eroded, as shown by Fig. 3(*a*), which is a view of part of a moulded phenolic disc, originally with a polished surface. In some homogeneous materials, microscopic pits are excavated at the periphery of a discharging void, as shown in moulded nylon by the dark tree-like structures illustrated in Fig. 3(*b*). These effects result in the well-known slow fall in electric strength with long application of stress.

For a given electrode arrangement and a given stress, the number of discharges per cycle is roughly constant, so that up to a limit set by thermal failure the life of insulation under discharges of moderate intensity is inversely proportional to frequency. Life tests at frequencies higher than normal are therefore legitimately accelerated, since the life expressed in total cycles is unaltered, although compressed into a shorter time. Results are thus obtained in a reasonable time even at the working stress, and this avoids introducing a different mechanism of breakdown, which may occur when a test is accelerated by increase of stress. Data of the kind shown in Fig. 4 are being obtained for many materials.[2] Comparison of curves *f* and *g* shows that removal of the resin "skin" from a filled moulding reduces the life nearly one hundredfold, by allowing penetration of the discharges along exposed interfaces between resin and filler. This emphasizes the advantage of homogeneous materials.

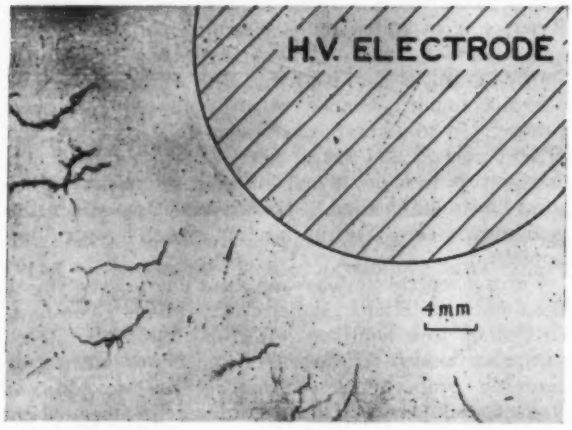
Too recently for inclusion in these books, it has been shown[3] that a more intense discharge streamer, which is



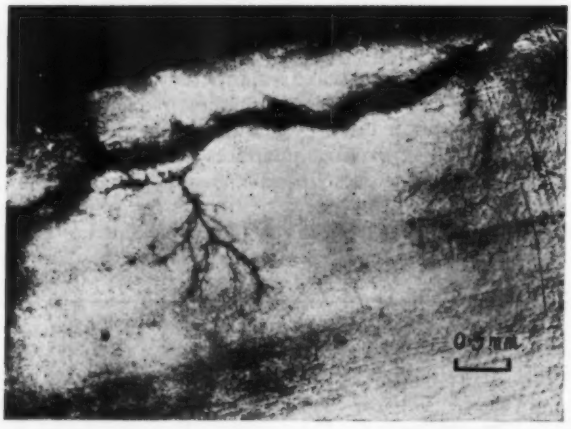
4 *Life in cycles of various insulating materials subjected to discharges, as a function of stress.* [*Howard, Mason and Parkman*]

(*a*) Polythene cable UR32.
(*b*) Polythene cable UR21.
(*c*) Polythene discs with cavity.
(*d*) Polystyrene discs (plasticized) with cavity.
(*e*) Polystyrene discs (unplasticized) with cavity.
(*f*) Moulded phenolic disc (nylon and cellulose filler) with moulded cavity.
(*g*) Moulded phenolic disc (nylon and cellulose filler) with machined cavity.
(*h*) Moulded nylon discs with cavity.

accompanied by higher stress in the material, can penetrate the surface and propagate rapidly within a solid, because of the stress concentration at its advancing end. This explains the long outstanding problem of the decrease in apparent electric strength with thickness, since the ratio of the average stress to that at the end of a streamer is smaller the greater the electrode separation.



5 *Channels formed below the surface of polythene subjected to discharges under oil* [*Mason*]

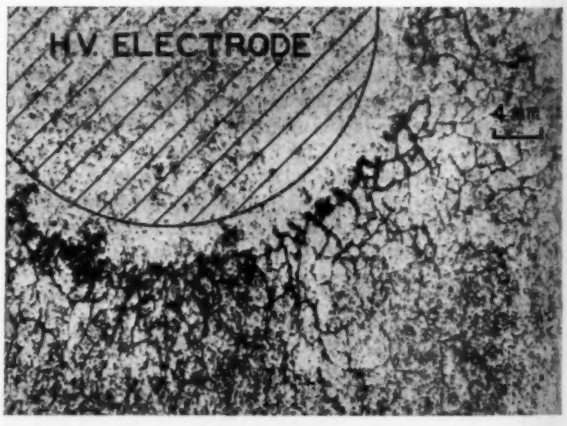


6 *Section along one channel of the specimen shown in Fig. 5, showing ramification into the material* [*Mason*]

Fig. 5 shows channels formed by this means just below the surface of polythene, during subjection for a few minutes to discharges under oil. Significantly, the channels begin well beyond the electrode edge, where the average stress is relatively low, because only the longer discharges have sufficient energy to penetrate the surface. Fig. 6, a longitudinal section, shows how a channel has ramified into the material, which would soon have been penetrated had the test been continued. Fig. 7 shows similar channels below the surface of synthetic-resin-bonded paper board. In the original, they can be traced microscopically to a distance of 30 mm from the electrode edge.

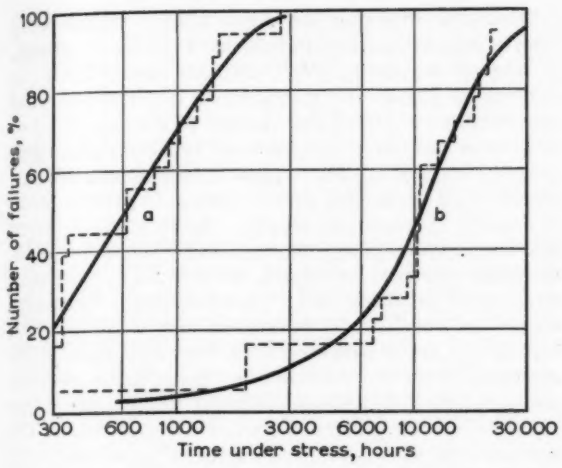
The value of a combined attack by chemists, engineers and physicists upon problems of insulation is rightly emphasized in Professor von Hippel's prefaces. The books, on the whole, do not meet the challenge. One is concerned mainly with physics; the other might have covered more fully the chemical aspects of insulation. This it does very well as regards the properties of new materials, but with little reference to the physical chemistry of such processes as thermal and electrochemical degradation, visco-elastic flow, moisture sorption, and ionic conduction. There are, indeed, single pages on some of these matters, but the ideas nowhere emerge coherently enough to influence the reader's habit of thought. The opportunity has been missed of presenting such changes through the unifying concept of a rate process,* although the first papers on dielectric loss and thermal degradation regarded as rate processes were American.

Electrochemical degradation is among the subjects too scantily treated, although the author of one of the articles in "Dielectric Materials and Applications" shared in its discovery. He, however, dismisses the matter in half a page, ignoring later work[4,7] in this country which put the subject on a firmer chemical basis. It has become clear that many apparently electrical



7 *Channels on and below the surface of s.r.b.p. board subjected to discharges under oil* [*Mason*]

* A rate process is one in which the rate of response to a change in conditions is controlled by the rate at which molecules receive, by chance, sufficient energy from thermal agitation to enable them to surmount an energy barrier that impedes the response in question. The majority of time-dependent processes are rate processes. They all have certain fundamental relationships in common, however different their apparent natures.



8 *Failure of capacitors by electrolytic deterioration* [*Church*]
(*a*) Unstabilized dielectric.
(*b*) Stabilized dielectric.

failures are really chemical or electrochemical in origin, and often associated with defects or impurities which are only microscopic in size or quantity. Engineers sometimes forget that ionic leakage currents must involve transport of chemical substances to the electrodes and that many insulating materials should be regarded as electrolytes of very low conductivity. This fact is illustrated by Fig. 8 for capacitors in which failure was due to the combination of nascent hydrogen, liberated at the cathode, with chlorine from an impregnant, to form HCl. Addition of 2% of azobenzene, which combines harmlessly with hydrogen, shields the impregnant from attack and increases the life of these particular capacitors, about 15 times. Some current work is directed to examining such reactions under a.c. stress.

The presence of free ions in a dielectric increases its permittivity at very low frequencies, and this effect can be used for the measurement of moisture content. Fig. 9 shows a dispersion meter[1,5] which was developed for this purpose by the Electrical Research Association and is produced commercially in this country.

Other results of electrochemical research may be mentioned. The resistivity of paper for electrical uses is increased fivefold by substituting calcium for hydrogen ions in the cellulose molecule;[6] microscopic traces of grease cause failure in polystyrene capacitors;[7] some lubricants used in the spinning of textiles may lower the insulation resistance of the yarn in humid conditions to $1/10^5$ of its normal value, with disastrous effects on its electric strength. Vitreous-enamelled resistors will fail in humid conditions by electrochemical corrosion owing to leakage currents at microscopic cracks in the enamel. These cracks are difficult to reveal optically but can be detected by the action of the leakage current itself on a photographic emulsion placed in contact with the enamel.

The alternative to the study of failures is the development of more resistant materials. This aspect is well covered by "Dielectric Materials and Applications," which describes applications of all the newer substances. There is already no lack of materials with good electrical properties, if thermal and mechanical limitations can be ignored. The present urgent need is for materials with desirable mechanical properties which will be maintained at high temperatures, even at some sacrifice of electrical quality. There are, however, fundamental difficulties in combining in one molecule all the desirable characteristics, and some of these are inherently incompatible, so far as present knowledge extends. Thus, although many recently developed materials have valuable special properties, the conventional ones still form the bulk of commercial insulation, especially in power applications. While both lines of progress should be pursued with all vigour, it does not yet seem likely that new materials can supersede, or even rival, improvements in those already existing.

This generalization requires qualifying. Polyethylene, for example, is nearly ideal for high-frequency cables at moderate temperatures, but its softness makes it useless for machines and limits its usefulness in power cables. An interesting development, presumably too late for mention in these books, is the cross-linking of polyethylene by β- or γ-irradiation,[8] which raises its temperature limit some tens of degrees and is especially valuable if the finished article can be irradiated. In common with other materials, however, as its thermal properties improve, the mechanical ones worsen, and the irradiated material can be neither moulded nor extruded. Similar limitations apply to the new fluorocarbon, polytetrafluorethylene (p.t.f.e.), which raises the temperature limit for organic insulating materials to about 250°C, but cannot be applied to conductors without great difficulty, except as a thin and rather unsatisfactory layer from an emulsion. Replacement of one fluorine atom in four by chlorine, to give polychlortrifluorethylene (p.c.t.f.e., or Kel-F), improves the mechanical properties at the expense of all the others.

The new molecularly-orientated thin films of poly-

9 *The dispersion meter, which measures the moisture content of insulation* [*Mole*]

styrene and Terylene (also known as Melinex and Mylar) constitute a real advance in dielectrics for special capacitors. Polystyrene is useful at high frequencies, having a low loss angle and high stability, but limited in use to temperatures below 70° C; its low absorption and extreme resistivity make it of interest for capacitors used in computers. Terylene film, which is still under development, offers much higher thermal stability, but at the cost, as usual, of the good electrical properties of polystyrene. It is unlikely to replace paper for power capacitors, but it may provide an equivalent type of capacitor for use at temperatures not exceeding 130° C. Terylene in impregnated-fabric form is a well-established and important advance. It has greater strength and permanence than cotton, and in combination with silicone varnishes can withstand a temperature of about 130° C. The new epoxy resins promise wire coverings and varnishes in a similar or slightly higher temperature range.

Many moulding materials are now available as alternatives to the conventional phenolic resins. In addition to the fluorocarbons already mentioned, and the well-known polystyrene and Perspex, there are melamine resins; nylon; a group of polyesters; copolymers of p.v.c. with polyvinylidene chloride, and several synthetic rubbers, with silicone rubber outstanding in stability at temperatures up to 150° C.

It is unfortunate that, of all these materials, Britain played a leading part only in regard to polyethylene and Terylene, and that she is falling seriously behind in the field of high-polymer chemistry. The electrical industry has good reason to press for more energetic support of this field, which is covered by no public research organization in this country.

Since these books, which are beautifully produced, are necessarily expensive, the prospective buyer will consider their contents in relation to his needs. "Dielectrics and Waves" is a clear and very readable textbook of physics, covering electromagnetic theory and the interaction of electric and magnetic fields with matter, together with enough chemical physics to explain the structure and bonding of molecules. Only in the widest sense is it concerned with insulation. The term "dielectric" is defined as including all non-metals, and "even metals as a boundary case." The subjects embraced therefore include ferromagnetism; semi-conduction; waveguides; and optical absorption in metals. The strictly "dielectric" aspect is somewhat crowded. Conduction and breakdown are given 17 pages, and dielectric loss a single page of rather limited discussion. This choice of scope is deliberate, and constitutes an attempt to create a common province for the chemist, engineer and physicist. But one may well feel, since the policy has been carried so far, that "Matter and Waves" would, by appealing to all engineers, have been a more appropriate title. Certainly all engineers will find the book a most illuminating introduction to the physical background of their work, and will admire the elegance with which seemingly unlike phenomena appear as special cases of a single general theory.

"Dielectric Materials and Applications" suffers badly from its origin in a symposium (dated 1952) by 22 authors. A 45-page summary of "Dielectrics and Waves" is followed by 85 pages on measurement of permittivity and permeability in lumped and distributed circuits. Half of this consists of charts and tables of functions relating to coaxial lines, perhaps out of place in so general a volume. The next 150 pages are shared among 15 articles, none exceeding 13 pages in length. Subjects range from microwave spectroscopy, through the insulation of conventional electrical apparatus, to the theory and construction of metal rectifiers. The more purely "physical" articles are mostly as informative as their length permits, and of the articles on insulation one may particularly commend those on breakdown of gases under pressure and on liquid dielectrics. Several of the remainder suffer from being either too brief or too superficial. The volume ends with tables and curves of permittivity and loss angle, measured at the M.I.T. laboratories, for about 600 materials, over the frequency range 10^2–10^{10} c/s and temperature ranges from 20° C to the limit for each material. This is by no means the least useful section of the book, thanks to the enormous industry of its compilers.

Particularly useful to English readers are the numerous references to published work, mainly American, although too many relate to either abstracts or popular accounts. One has the impression that much work on insulation carried out in the United States is never fully reported and so fails to establish an accepted theoretical background among insulation engineers.

The preface to "Dielectrics and Waves" expresses a hope that the book may be a trumpet of Jericho to break down the walls between engineering, chemistry and physics. The success of this effort as evidenced by "Dielectric Materials and Applications" is less than complete. However, it can be calculated[9] that Joshua himself lacked even partial success until at least the 91st blast. One earnestly wishes Professor von Hippel more rapid progress in a good cause.

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9 The Book of Joshua, Chapter VI.

HOME EVENTS

LONDON

EXTRA MEETING

At an Extra Meeting on the 12th May, 1955, a discussion on *Image Intensification in Radiology* was opened by Dr. W. J. Oosterkamp and Dr. G. M. Ardran. This centred mainly on the system of image intensification using an electronic image-intensifying tube. In this tube a photocathode is in contact with a fluorescent screen, the incident X-ray image being converted into an image of photo-electrons which are accelerated to 25 keV and then focused on a viewing screen. The image, which is some nine times smaller than that on the X-ray screen, is about 1 000 times brighter and can be viewed through an optical microscope objective or photographed direct. In medical fluoroscopy, the fluorescent screen has to be used at low visual brightness because of the radiation hazard to patient and operator; the image intensifier, however, now offers the choice of either a brighter image of better definition or a reduction in radiation dose.

As one speaker pointed out, in contrast to medical work where a balance has to be struck between dose and visibility, in industrial radiography a parallel compromise has to be made between economy and visibility. Curves were shown of percentage sensitivity against thickness for steel and aluminium samples examined by both fluoroscopic and radiographic techniques, with and without image intensification. For comparable thicknesses, image intensification gives better results with the fluoroscopic process, but image blurring increases with thickness, spurious light spots being a further inconvenience. Image intensification was thought to offer possibilities where normal radiography becomes too costly, and the reduction of 2–2½ kV in applied voltage is an additional advantage.

Another contributor spoke of his experience of the use of the image intensifier in medical fluoroscopy, first for applications in which some instrumentation was required, e.g. in cardio-catheterization, and secondly in angiocardiography, a process in which the passage through the heart of an opaque contrast medium was studied. The latter method was preferred to the conventional method using rapid full-size films. A cinematograph film of the angiocardiography of a baby's heart was shown.

Commenting on suggested improvements in image intensification methods the first opening speaker said that larger field sizes—5 in diameter for children and 8–12 in diameter for adults had been proposed—were possible with experimental tubes already produced, but these were still far from the production stage. Another speaker proposed the use of radioactive sources as an alternative to X-rays, e.g. a soft γ-emitter, or a β-emitting isotope generating X-radiation; this was thought to offer only limited prospects owing to the high level of quantum fluctuations and the large amount of radioactive material required to compete with simple X-rays. Blurring still remains the major cause of lack of definition. The use of higher accelerating voltages, also suggested in the discussion, would be precluded by cold emission from the cathode space, the tube then becoming unstable. If γ-rays or very hard X-rays were employed, a thicker primary screen would be necessary with consequent increased blurring. The television pick-up method of image intensification might give increased contrast with better perceptibility, but it is impossible to improve the signal/noise ratio of the primary image, pick-up tubes possessing their own background noise.

MEASUREMENTS SECTION

Summer Visit

The Summer Visit of the Section was held on the 17th June, 1955, in the warm and sunny weather which has become a tradition for this favoured visit. For practical reasons our hosts were forced to limit the party to 100 members and ladies, and unfortunately a long waiting list of disappointed applicants was unavoidable.

The party was received at the works of Electric & Musical Industries at Hayes by Mr. B. E. G. Mittell and Mr. H. A. M. Clark and conducted through the works. The party saw, among other activities, the manufacture of cathode-ray tubes and long-playing records, and the assembly of television and radio sets; they also visited the demonstration and music test rooms, where they had the experience of hearing a record of Chinese vocalists. Lunch was served at the Castle Hotel, Windsor, at which Mr. Mittell welcomed the guests and asked each lady to accept a gramophone record as a souvenir of the visit. Mr. M. Whitehead, the Chairman of the Section, in thanking the Directors for permitting the Visit, expressed appreciation of the freedom that had been allowed to the parties touring the works—an indication of their broad outlook on the interests of the profession. It was a pleasure to have the ladies, many of whom suffer through the homework which members of committees have to complete, to accompany them and to enjoy with them the excellent hospitality provided.

After lunch the party proceeded by a picturesque route through Windsor Great Park to the Royal Horticultural Society's Gardens at Wisley, where tea was taken.

The evening was spent at Horsley Towers, the training establishment of the Central Electricity Authority, where the visitors were met by Mr. T. J. Roberts and Mr. K. M. Maxwell, and conducted around the beautiful gardens

Members and their ladies at lunch in Windsor during the Summer Visit of the Measurements Section

and park in which the house is situated. They also visited the chapel and cloisters with their singular and colourful architectural style. In the demonstration rooms they saw a very complete collection of models and equipment including water-tube boilers and turbo-alternator sets, coal-pulverizing plant, carbon-dioxide recorders, instrument panels, switchgear, voltage regulators, circuit-breakers, and measuring and controlling instruments. There were also other exhibits illustrating methods of illumination, and the precautions taken for safety.

Mr. J. Eccles, Deputy Chairman (Operations) of the C.E.A. and President of The Institution, presided at the dinner in the Great Hall. Mr. Eccles in welcoming the visitors, said he appeared before them in a somewhat Jekyll–Hyde capacity, and he wished to assure them that Horsley Towers was not the summer residence of the Deputy Chairman. The house had formerly been the war-time headquarters of the C.E.B., and its purpose was now the training of personnel. The technology of electricity supply was constantly advancing, and the Authority felt in duty bound to keep its staff up to date. Over 2000 employees had taken courses. Mr. Eccles congratulated the Committee on the itinerary for the Visit, and although he had learned of the agreeable manner in which the morning and afternoon had been spent, he did not consider that music and flowers provided sufficient sustenance for measurement engineers; he was therefore glad they had accepted his invitation to dinner.

Mr. M. Whitehead, in expressing the thanks of the Section to the C.E.A. for their hospitality, said that they were honoured by the presence of Mr. and Mrs. Eccles. The visitors had been very impressed by the collection of models, and they were grateful to the guides for the explanations given, and to Mr. Roberts and Mr. Maxwell, who had done so much to make the visit a success.

BELFAST

NORTHERN IRELAND CENTRE

Mr. J. W. Bunting opened the second half of the session with his paper entitled *Safety in the Use of Portable and Transportable Electrical Equipment in Industry*. Safety is a vitally important consideration, but by its very nature it lacks excitement and many members may have attended the meeting in Queen's University, Belfast, on the 8th February, 1955, from a sense of duty rather than with the prospect of a pleasant evening. Those who came in this mood reckoned without the lecturer, for Mr. Bunting covered a difficult subject in a masterly fashion. He dealt with serious things without gloominess but never flippantly, and—most important—he opened the eyes of many to the fallacy that "anything under 250 volts is safe." Every electrical engineer who has not heard this paper delivered should read it himself. Many will thereafter resort to heavy rubber soles and heels and work with one hand in the pocket.

The discussion seemed to have been inspired by the lecturer, for it was constructive and never dull. From a senior civil servant the Centre learnt how Northern Ireland compares with Great Britain in the matter of industrial electrical accidents; from a statistical viewpoint it seems that she follows in these the familiar

step-by-step policy. There was evident, however, a certain lack of statistical data, for Northern Ireland had had no fatal electrical accidents in the preceding twelve months. An experienced electrical contractor showed how easily electrical accidents can happen. One speaker complained—and the author readily agreed—that the importance of applying, and of knowing how to apply, artificial respiration had not been sufficiently stressed in the paper. The general opinion was that all present had enjoyed a useful evening.

The Annual Dinner-Dance at the Grand Central Hotel, Belfast, was a very pleasant function indeed. The occasion was marked by a visit from the President, Mr. J. Eccles, and the Secretary, Mr. W. K. Brasher. Mr. Eccles is an Ulsterman and it is always a pleasant thing to meet or hear from, a "local boy" who has been successful. On this occasion, however, anything the President had to say was of extra special interest, for he had been entrusted, a few days before, with many millions of pounds to build atomic power stations all over the United Kingdom. Pressmen waited with pencils poised for every word he uttered, and his speech at the Dinner was listened to with closer attention than even courtesy demanded. It need hardly be said that no disclosures of policy were made. The Centre was also honoured by the presence of Mrs. Eccles and Mrs. Brasher, Dr. Cuffe of the Irish Branch and Mrs. Cuffe, and the local Chairmen of the sister Institutions. Sir Percival Brown, the Lord Mayor of Belfast, and Lady Brown were guests and Sir Percival responded to the toast of "Our Visitors," proposed by the Chairman, Major P. L. Barker.

Returning to work again at its March meeting, the Centre heard Mr. A. J. Frances deliver his paper on *Electricity in the Wool Textile Industry*. It is said that Ireland, having been forcibly deprived of her woollen industry (a very long time ago), set up her linen industry instead. If that is so she probably lost nothing in the long run, for her linen is equally as famous as Britain's woollen goods. For this reason and although a large part of Northern Ireland's population is engaged in textile work, a paper on the manufacture of woollen goods seemed to many members slightly irrelevant, and some even suggested that the Papers Committee had got mixed up. However, the paper showed how wrong they were, because, whether for the manufacture of linen, cotton, woollen or other cloth, textile processes have a remarkable similarity, with just sufficient contrast of detail to prevent the dullness of a story that has been told before. The paper was informative as also were the films which illustrated it, and the discussion was searching and useful.

On April 12th Mr. M. McGregor Ross read his paper on *Equipment of Instrumental Accuracy for Recording and Reproduction of Electrical Signals using Cinematograph Film*. In dealing with this very specialized subject Mr. Ross succeeded in the almost impossible task of presenting his material in a form attractive to the majority of members without noticeably detracting from its value to the specialists concerned. The discussion which followed was much less intelligible to the majority. In fact, it was a specialists' party; they certainly seemed to enjoy themselves, and Mr. Ross appeared to be in his element in Belfast.

The Faraday Lecture is regarded in Northern Ireland by many outside The Institution, and indeed outside engineering altogether, as an affair that must not be missed. This year the Sir William Whitla Hall of the Queen's University was packed when Mr. T. B. D. Terroni took us through the years *From Carrier to Courier in Communications*. Excellent stagecraft and magnificent demonstration equipment have become a characteristic of the Faraday Lecture and it is only too easy to assume that they make the lecture and to forget that it is the lecturer who makes them. The people who attended on this occasion had a great experience and went away feeling that they knew a lot more about a very intricate subject than they did before.

This year it was decided that the informal talk to follow the Annual General Meeting, a very popular feature in recent years, should be open not only to members but also to their wives and friends. Mr. J. Johnstone, the Postmaster Controller for Northern Ireland, gave a lively and entertaining talk on *The Post*. It was illustrated by two excellent Post Office films and, even when the projector failed for a time, Mr. Johnstone "used the cloak of adversity as a garment" and carried on in witty style, true to his reputation as a speaker and

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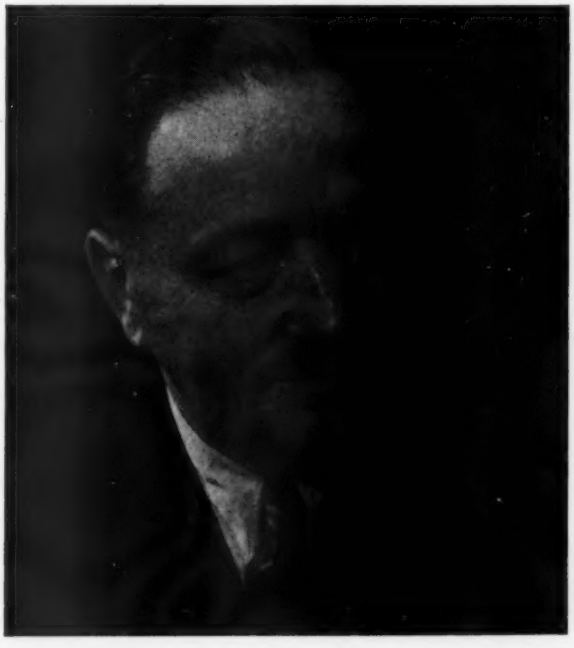
Mr. T. B. D. Terroni



lecturer. The meeting was thoroughly enjoyed by members and visitors alike. D. S. M.

The pigeon posts of Genghis Khan
A mosaic illustration from a film shown at the Faraday Lecture

SWANSEA

WEST WALES (SWANSEA) SUB-CENTRE

An informal meeting was held on the 17th May, 1955, in Swansea University. Its primary object was to provide information, and to enable a discussion to be held, on The Institution's new examination requirements. Professor D. N. Cass-Beggs had kindly arranged for the meeting to be held in the University, and for it to be preceded by a tour of the new Engineering Laboratories, thus providing an excellent background for the subject of the evening. The meeting was addressed by Mr. N. C. Stamford, The Institution's Education Officer, on the new examination requirements. A number of local members believed that the examinations had been raised to an unduly high level, and that too much stress was thus being laid on the academic side of the training for the electrical engineering profession. Mr. Stamford, therefore, had no easy task before him, but he quickly showed that he was master of the situation. He gave a brief history of the Institution examination, showing how it had been necessary periodically to revise the syllabus, and how the standard of exemption through the National Certificate scheme had been correspondingly raised, and stressed that the percentage of passes had not been greatly affected as a result. The excellence of his delivery, and the sincerity and enthusiasm he showed in dealing with all points, won him the full applause of the meeting. The discussion which followed was mild in comparison with what had been expected, showing how effectively he had covered his subject.

The Sub-Centre held its Summer Meeting on June 23rd. Making an early start from Swansea, the party proceeded to the Rheola works of the South Wales Aluminium Co., at Resolven, where an insight was gained into the production of light-alloy strip and sheet. The route lay northwards from Resolven, and a stop was made at Brecon for lunch; this was followed by a journey through picturesque country to the Elan Valley, where a series of dams provides water for the city of Birmingham. A visit was made to the hydro-electric station at the base of the Caban Coch dam. This station, although small, provided considerable interest, and was studied in minute detail. Finally, the party inspected the famous Claerwen dam, making a tour of the tunnels within it. A call was made at the Elan Valley Hotel for a meal, after which the return to Swansea began. A record of this highly successful meeting would hardly be complete without mentioning that time was found to pause for light refreshment on the homeward journey. R. F. D.

WALTON-ON-THAMES

SOUTHERN CENTRE

A most successful Summer Meeting was held on the 17th June, 1955, at Hampton Court and Walton-on-Thames. Coach parties were made up from several districts, and members, their ladies and guests met for lunch at the Mitre Hotel, Hampton Court, by kind invitation of the Hackbridge and Hewittic Electric Co., after which Mr. E. A. Logan, the Centre Chairman, expressed most cordial thanks for the hospitality extended.

In the afternoon a party toured the Walton-on-Thames works of the company, where they saw many transformers, of capacities up to 120 MVA, in various stages of manufacture, and had a glimpse of the enlarged impulse-generator section now in course of erection. In the rectifier section special demonstrations were given of the fabrication of glass bulbs, and, after a tour of the assembly shops, the party saw a 550 kW 1500-volt mining traction unit in operation. Meanwhile the ladies were exploring Hampton Court Palace with an experienced guide.

The parties reassembled for tea at the hotel, and afterwards left for their various destinations. The company totalled 69, and their general opinion was that it had been a most enjoyable day and reflected credit on the organizers. H. W. H.

NEWS *from Abroad*

ODE TO THE *JOURNAL*

(From a member in Australia)

'Tis many years since first your form I knew,
An austere maiden clad in sober blue.
You've been my friend, tho' aye your heart inclines
To men of mightier words and mystic signs.
Oft-times our paths diverged. You'd take your way
To TV, Radar and the Cosmic Ray,
While I, earth-bound, did like a clod refuse
To leave my boilers and my B.T.U.'s.
Stern duty was the only guide you knew,
Which left me, like your cover, rather blue.
Old girl, I hail your efforts to go gay;
A Titian hair-do, dress the Dior way.
Your path of duty broadens, and you choose
"To elevate, to interest and amuse."
A column for the engineering Miss?
Perhaps you'll even print such stuff as this!
But ne'er forget the power of printed page.
TV stays but a moment, you an age.
Per contra, *as a famous writer said,*
His sins were scarlet, but his books were read.

C. S. JEFFREY, Member.

Mr. E. A. Logan, Chairman of the Southern Centre, with Mr. A. E. Nicol, Director of the Hackbridge and Hewittic Electric Co., and other members of the Centre, at Walton-on-Thames (see opposite page)

AUSTRALIA

QUEENSLAND COMMITTEE

Approximately 20 members availed themselves of the kind invitation extended through Professor S. A. Prentice to make an inspection of the electrical laboratory of the University of Queensland, on the evening of the 12th May, 1955. Noteworthy amongst the very interesting exhibits featured by the laboratory staff and students were the recent developments in impulse testing plant, and the application of an automatic field-plotting apparatus for the study of electric, magnetic and similar field patterns.

The impulse testing plant includes a six-stage Marx-type generator and auxiliaries, which can produce a test voltage of comparable magnitude and waveshape to that occurring in practice. The 200 kV d.c. charging source has been completed, and the maximum output is approximately 900 kV. This plant is being used in research work and for tests of power system equipment.

At the close of the inspection, Mr. J. S. Just, Chairman of the Queensland Oversea Committee, thanked the university staff and students for a most interesting evening, to which Professor Prentice made a suitable response.

A. S. F.

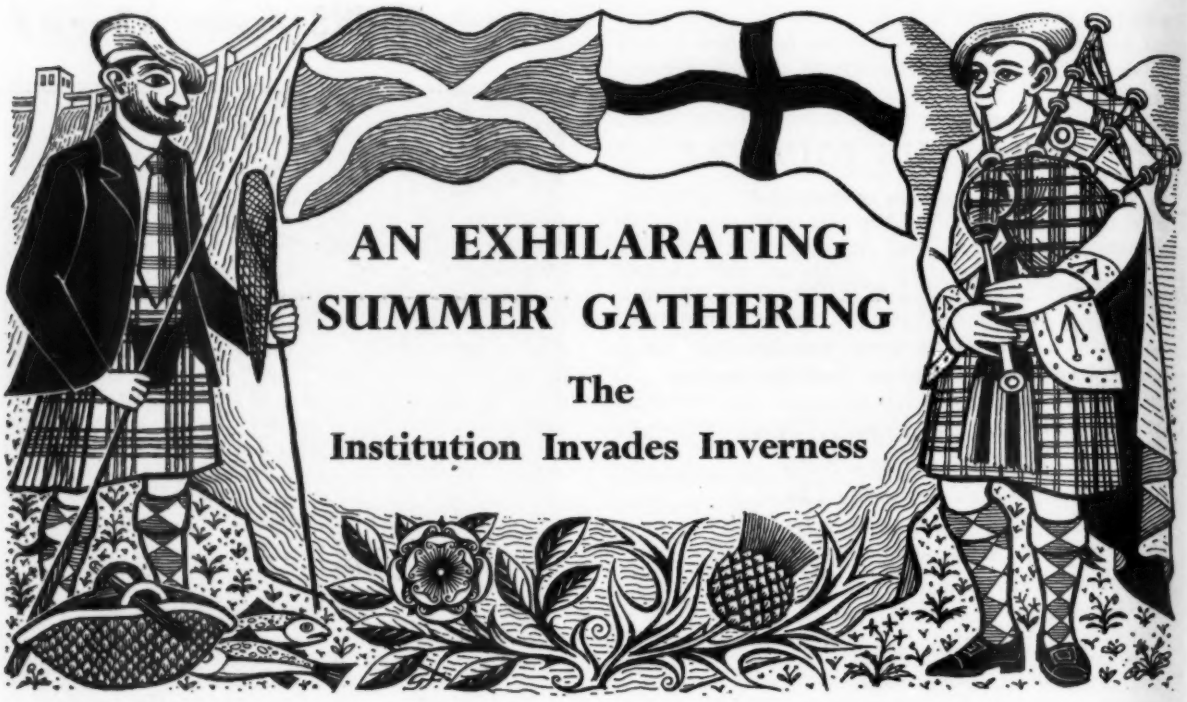
OVERSEA ATTENDANCE REGISTER

During the period 1st July to 31st July, 1955, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

APSIMON, W. I. (**Freetown**).
AUST, E. A. (**Calcutta**).
CLARK, R. G. (**Boston, U.S.A.**).
CLARKE, W. W. H., B.Sc., Ph.D. (**Ottawa**).
COTSWORTH, W. M. (**Port of Spain, Trinidad**).
DAVIES, J. (**Johannesburg**).
DE MEL, C. H. J. (**Kandy, Ceylon**).
DOWNEY, J. V. (**Springs, Transvaal**).
GOODCHILD, J. R., B.Sc.(Eng.) (**New Delhi**).
KAMAT, G. M. (**Bombay**).
MUNRO, G. H., M.Sc. (**Sidney**).
PENZER, J. (**London, Ontario**).
RUTHERFURD, W. G., B.E. (**Singapore**).
SIVAGNANASUNDERAM, T. (**Colombo**).
STANDEN, M. H. L., M.A. (**Nairobi**).
WADE-COOPER, F. (**Calcutta**).
WATERS, G. E. (**Montreal**).
WELCH, J. W. F. (**Auckland**).

REPORTS FROM MEMBERS

The Editor would be glad to receive more short accounts of oversea members' experiences that are likely to interest other readers of the *Journal*. Photographs (in the form of glossy prints) of local electrical engineering events, groups of members, important visitors, etc., will also be very acceptable.



AN EXHILARATING SUMMER GATHERING

The Institution Invades Inverness

"My heart's in the Highlands . . . The birthplace of valour, the country of worth"

Nearly Cancelled

NOT all of us who took part in the 1955 Summer Meeting of The Institution realized how close it came to being cancelled.

On Wednesday, June 1st, something of the war-time atmosphere of an operations office had permeated the administrative section of The Institution's headquarters. Rarely had the fate of a large and important event in The Institution's future programme been so uncertain. After three days of haphazard trains and conflicting reports of the probable national dislocation from continuing strikes, forecasts of the course of the next ten days had become an activity for Old Moore rather than the organizers of a Summer Meeting. But on June 1st the Institution Secretariat had returned to work after the Whitsun holiday knowing that a decision whether to hold the Meeting—due to begin in Glasgow in five days' time—must be rapidly made. The General Purposes Committee of the Council met, the opinions of officers of the Scottish Centre and of others concerned on the spot were obtained, some 30 members in London intending to join in the Meeting were sounded, and as a result of a day's intense activity it became clear that not only would it be possible to hold the Meeting, substantially unchanged, but most people did not want it cancelled. The President decided on the Wednesday evening that the Meeting should in fact take place. As it turned out, not one of the 475 members and ladies who met together in the Highlands would later say that this decision was wrong. The Meeting was truly to prove a huge success.

Later that evening a letter was sent to all of us whose names were on the lists of the Meeting confirming that it was on and giving news of available transport to Glasgow. The letter also showed how we should be told if cancellation at the week-end were to become necessary through a deepening of the national crisis. Happily, in the next few days only about 15 people had to drop out because of the strike, and the sole notable change in the original programme was the inescapable scrapping of an all-day railway excursion to Skye. The Summer Meeting in the North of Scotland was to be the largest and most involved one that The Institution has staged. The President's decision must have especially relieved the Scottish Centre Committee, who had so zealously worked for some nine months at the elaborate and intricate arrangements; the admirable fruit of their efforts did not indeed deserve to be dashed to the ground.

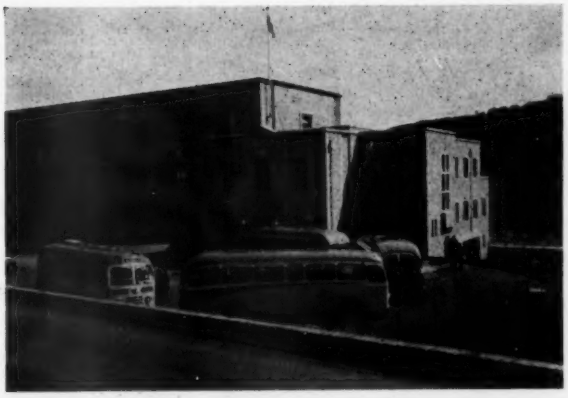
From Glasgow to the Highlands

The programme of the Meeting had three phases: (*a*) Assembly in Glasgow in the evening of Monday, June 6th, and on June 7th a coach journey via Fort William to Inverness; (*b*) Four nights' stay in Inverness, with visits and tours—both technical and sightseeing—in the daytime, and entertainment

in the evening; and (*c*) Return journey on Saturday, June 11th, by coach via Pitlochry to Glasgow or Edinburgh, with dispersal on arrival. Some of us skipped phase (*a*), travelling direct to Inverness, but the majority were in Glasgow by the late afternoon of Monday, having reached it by car, by plane, by coach, and even by train (in surprising comfort) at various times on Sunday and Monday. We found Glasgow basking in warm inviting weather that heralded a mild and nearly rainless week in Inverness.

On Monday evening the Lord Provost and Magistrates of the City of Glasgow kindly accorded us a Civic Reception, and this took place in the imposing City Chambers, built in 1883–88 and lavishly decorated with marble, mosaics, mahogany, satinwood and tapestry. The Lord Provost, Mr. Andrew Hood, made a speech of welcome, and the President replied. Afterwards we were entertained with some charming singing, religious and secular, by the famed Kirkintilloch Junior Choir, and by a dance in the superb Banqueting Hall that lasted until midnight. The Meeting had begun enthusiastically and in good heart.

After early breakfasts on June 7th we assembled from various hotels at a central point, where we made acquaintance with the fleet of nine modern coaches, resplendent in chromium and paint of a shade approaching electrical blue. These were to form the backbone of our transport on the next five days. They were fitted with a v.h.f. radio intercommunication system, and we soon learnt that the movements of the fleet were to be closely ordered from a flag-car (wearing the pennant of Commodore J. H. P. de Villiers, S.C.) at the front of the line. This "intercom." was to be invaluable for directing coaches to the right hotels at stops for meals and for encouraging drivers to press on swiftly when the fleet was more than usually astern of schedule. Mr. de Villiers, who with Mr. R. L. Stanley, worked unstintingly before and throughout the Meeting for its success, skilfully controlled the fleet's movements, and dealt with incipient stragglers with an assurance that many a Commodore of a war convoy would have envied. Nevertheless some coaches that had internally mounted aerials caused difficulty at first, and there was plenty of vocal entertainment on the loudspeakers; these were enlivened also by the voice of Mr. Banks of the North of Scotland Hydro-Electric Board, who regaled us with a running commentary on items of interest to be viewed from the coaches, together with convincing details of the kidnappings, hangings, murders, battles, and massacres that are the warp and woof of Highland history.

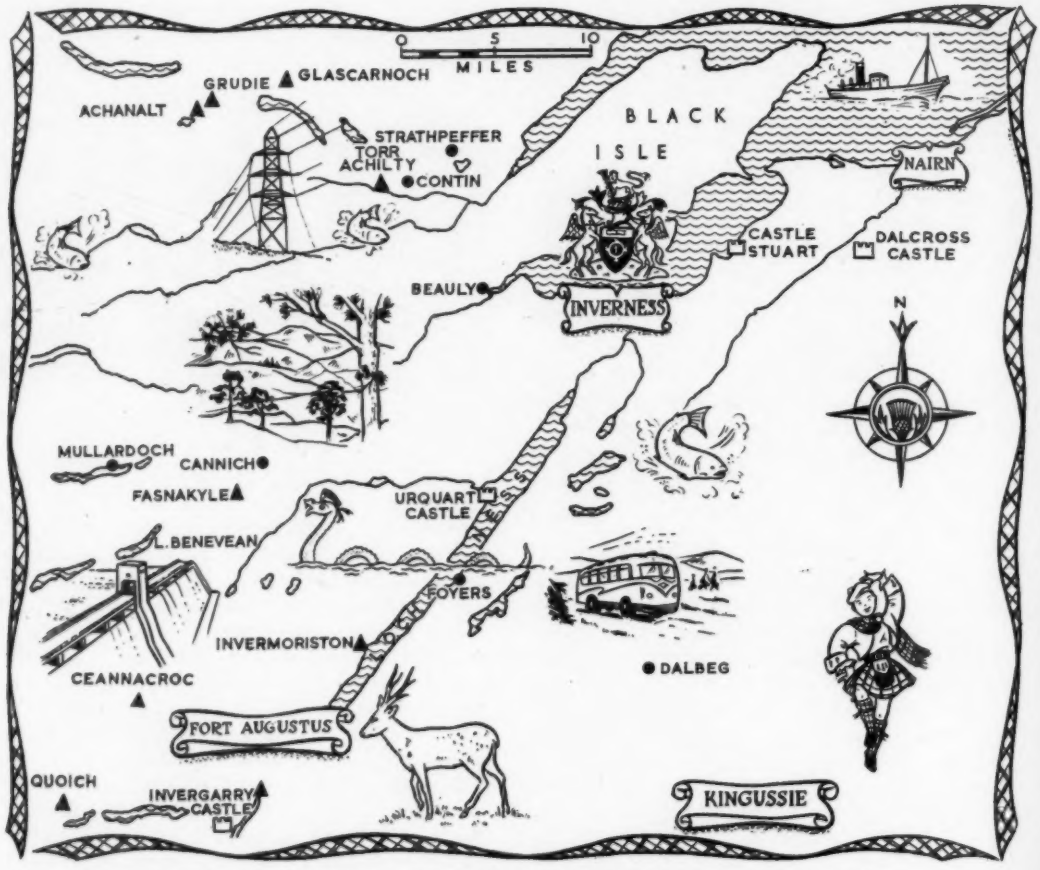


Part of the fleet of coaches at Fasnakyle power station, which is faced with yellow Greenbrae sandstone

Mr. and Mrs. J. S. Hastie at Fort William, with Ben Nevis in the background

Commodore de Villiers' unbounded energy had got us all to the fleet of coaches in Glasgow by 8.45 a.m.—except for two chemical enthusiasts who boarded a coach full of metallurgists that was heading for the Lowlands. The route to Inverness lay initially by the Boulevard out of Glasgow, past Strathleven switching station, which links the Hydro-Electric Board's lines with the Grid, and along the west side of Loch Lomond. There were low clouds in the air that shrouded the higher peaks such as Ben Lomond, but these were soon to clear, for a strongish wind sprang up—a wind which treated a part of the Meeting to its only live example of Highland warfare. A medium-sized conifer, encouraged by Aeolus, fell in front of the rearguard of the fleet in an attempt to deny it access to remoter Scotland. Luckily it mistimed its attack, dropping a few yards ahead of the last coach, which escaped with some scratched paintwork on its bows. Nothing daunted and quite unhurt, the passengers manhandled the offending tree down the bonnie, bonnie bank into the loch.

We stopped in the MacFarlane country at the Loch Sloy power station on the side of Loch Lomond (the station is named after the catchment area in the mountains), both to view it, and to drink some coffee through the kindness of the English Electric Co. The power station, which has the largest output of any in the Hydro-Electric Board's domain and has been in full commission for 4½ years, gave those unfamiliar with the work of the Board an indication of the high standard



Campaign map of the Inverness area (the black triangles represent power stations)

of design, maintenance and cleanliness that they would see farther north. Not so satisfactory are the pipes of the penstock, which, though painted green, scribe an ugly scar for several hundred feet down the hillside.

Time did not allow a visit to Loch Sloy itself and the coaches moved off to thread their way, by the Falls of Falloch and on through the wildness of Rannoch Moor and Glen Coe, to Loch Leven, traversing the country of the MacGregors, MacDonalds and Campbells; in this district there was much material for the tales of carnage from the loudspeakers. The road which hugs Loch Leven for some fifteen miles and passes the aluminium works at Kinlochleven is exciting, and although many of us were by now hungry for lunch, it was with some regret that we snatched a glimpse of Ballachulish across the loch and then headed away towards Fort William.

Our hosts for lunch in Fort William were the English Electric Co., and we were split between several hotels, where we had our first taste on the trip of that delectable fish the salmon, which was to demand much of our attention during the following days. At the Highland Hotel The President put into words the party's gratitude to its hosts and the pleasure felt by members that Sir George and Lady Nelson were present at the Meeting—at some personal inconvenience, for Sir George had only just returned from America and had not even had time to go home before leaving for Scotland. In replying for the English Electric Co., Sir George recalled his long association with Scottish hydro-electric projects and expressed his appreciation of post-war developments. He also declared his pride in "this great Institution" and his pleasure that the Meeting had been supported by so many members. His special remarks about the splendid part played by the ladies will be warmly echoed by all.

After lunch we were conducted round the Fort William works of the North British Aluminium Co., which produce aluminium from alumina in electrolytic cells, or furnaces, and include a large hydro-electric generating plant which has a greater annual energy output than any other in Scotland. The alumina, obtained by refining bauxite, is mainly brought up to Fort William by ship through Loch Linnhe. Everyone seeing the works was advised to deposit watches and cameras at the office, since the heavy currents (about 100 000 amp), used in the electrolytic cells produce intense magnetic fields throughout the refining shop. Fittingly, the busbars carrying these currents are made of aluminium.

The hydro-plant supplying, and adjacent to, the works is connected by pipe-line and tunnel to two lochs in the moun-

tains near Ben Nevis. Impulse turbines driving d.c. generators are used; the factory operates continuously on a seven-day week, and about 450 million kWh are generated every year. After the tour of the works, we appreciated the tea that was kindly arranged by the Company.

Leaving Fort William, we had from the coaches a magnificent view of Ben Nevis with its awesome north face, every crag stark and challenging in the clear mountain air—one might travel the road a hundred times and never again see the mountain under such perfect conditions, so frequently does it wear its cloak of mist or clouds. Our route now lay by the Great Glen ranch, Loch Lochy and the Caledonian Canal, to the northern side of Loch Ness. Here conversation inescapably turned to the monster, and over the loudspeakers came the news that a Scottish member had offered £10 (Scots) to the first person to see it; but he was not leaving the vast depths of his magnificent loch for our sakes. Our progress along the loch, through the country of the Frasers and the Grants, in fact continued uneventfully until we reached Inverness about 7.15 p.m.

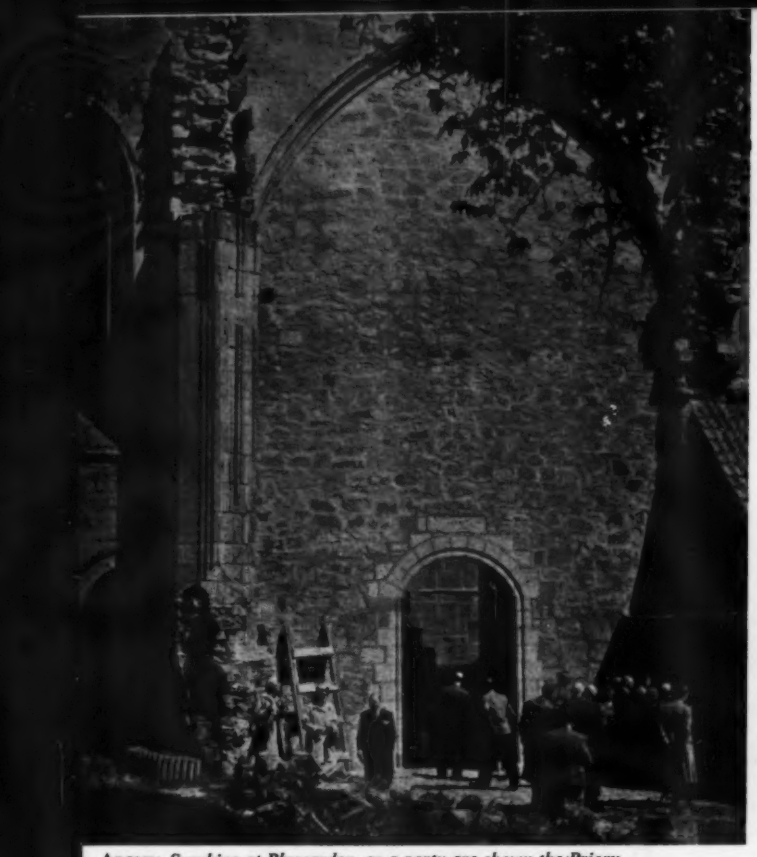
In and Out of Inverness

In Inverness, owing to the perseverance of our organizers, no less than 20 hotels were waiting to receive us, some of them several miles from the Caledonian Hotel, which lies in the heart of the town near the River Ness and was to be our coach station, assembly hall, entertainment palace and operations office. This galaxy of hotels was a result of the large numbers, and it necessitated complex transport arrangements for moving people to and from the Caledonian before and after the visits and evening functions.

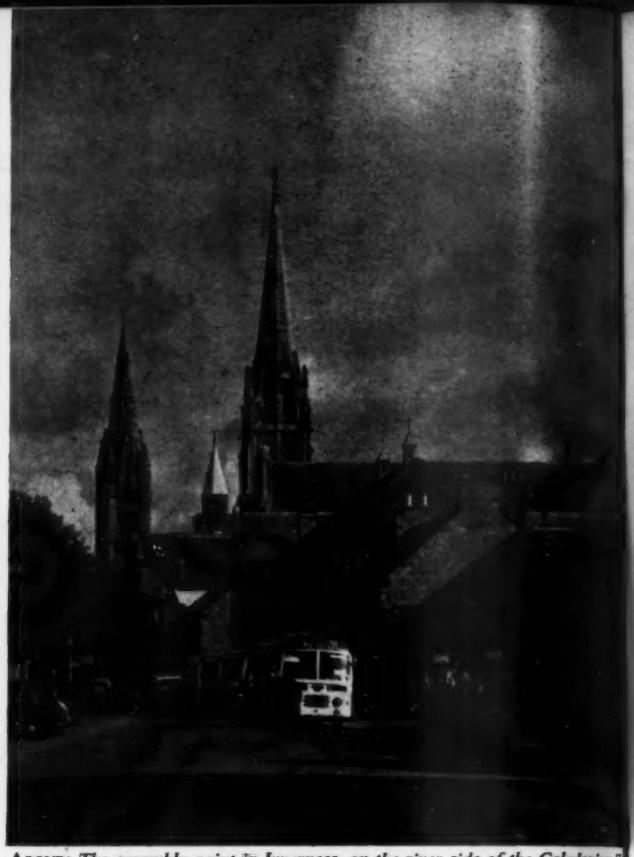
We spent from Tuesday evening to Saturday morning in the "Capital of the Highlands," and a first-rate programme, blending interest, instruction and entertainment, filled the three days and much of the four nights. "Boredom" is not a word that is used much in the all-crowded boom days of 1955, but if it should be large in any member's personal

One of the Meeting's pipers plays to members and ladies outside the Caledonian Hotel, Inverness

A cheerful and expectant group before the tour of Mackinlay and Birnie's whisky distillery in Inverness



ABOVE: *Sunshine at Pluscarden, as a party are shown the Priory*



ABOVE: *The assembly point in Inverness, on the river side of the Caledonian Ri*

BELOW: *Looking across the River Ness to Inverness Castle*

BELOW: *Mr. G. D. Banks, of the Hydro-Electric Board, embarks for a trip*

vocabulary, he could do no better than take a few days of a Summer Meeting as a remedy.

On the first night in Inverness we were welcomed by a member to whom all of us at the Meeting owe a great deal, namely the late Mr. T. Lawrie,* then General Manager of the North of Scotland Hydro-Electric Board. He introduced us in an illustrated talk to the Board's engineering and piscicultural pursuits and set the stage for many of our expeditions during the next few days. We now at least partly realized how important the salmon is in hydro-electric engineering. (By the end of the Meeting many of us were convinced that salmon breeding and protection are an alternative, if not a compulsory, subject in The Institution's new Examination Regulations.)

The main attractions in our daytime programme were indeed the all-day visits to the hydro-electric installations—completed or in progress—in the mountains and glens of Inverness-shire. On each day there were three such visits available, in the Conon Valley, the Glen Affric, and the Glen-Garry–Glen-Moriston districts, all lying to the west of Inverness. All three of these tours were admirable, and they embraced a great variety of Highland scenery, dams, power stations, and excellent luncheons kindly provided by the Hydro-Electric Board or the Mitchell Construction Co., not to mention other refreshment by various organizations.

An alternative all-day tour was one whose route lay eastwards to Culloden Moor, Johnston's woollen mills at Elgin, and Pluscarden Priory. The woollen mills specialize in cashmere and other rare wools, that of the Peruvian vicuña being truly quoted as "not for the common people but material for emperors." No husband in the party tried to look imperial when he learnt the price of this wool, but each lady was allowed to choose for herself a fine tartan cashmere scarf. The monks at Pluscarden Priory are hoping to rebuild it within the next 20 years. They specialize in stained-glass work; some electrical installation is also done, but in the words of the Father who conducted one of the parties, "this would probably shake the factory inspectorate to its foundations."

Shorter visits in and around Inverness which occupied a morning or afternoon included tours of a malt-whisky distillery and a woollen mill in Inverness; a coach tour southwards to Foyers, Loch Mhor and Loch Duntelchaig; and an inspection of the works of Resistance Welders Ltd., Inverness's only electrical manufacturing firm, each party having lunch as their guests.

Some isolated impressions of these visits are given later, but now follow a few paragraphs about the evening events.

On Wednesday after dinner we were given a civic welcome by the Provost and Magistrates of the Royal and Ancient Burgh of Inverness in the Northern Meeting Rooms, and in this the warmth of Provost R. Wotherspoon's words to us all as we came in, his assurance that the tranquil weather was going to hold, and his genial smile throughout the evening brought a real glow to the reception. The entertainment in the charming ball-room included a polished display of Highland and Scottish Country dancing by a team of young girls, which was later followed by our amateur efforts at some of the dances when the floor was open to members and ladies. The reception and entertainment were most surely a delightful close to our first full day in the Highlands.

On Thursday morning, if we allowed ourselves time for a paper at breakfast before hastening to the Caledonian Hotel, we learnt the welcome and almost domestic news of the Birthday Honours awards to Sir George Nelson, Mr. Harold Bishop, and Mr. A. F. Cross, Mr. J. Ritchie, and Mr. W. Smith, linemen of the Hydro-Electric Board. Sir George Nelson received personal congratulations at an informal lunch on Thursday in the Glen Affric Hotel, Cannich, and again at the President's Dinner in the evening.

Thursday evening found most of us in the Caledonian Hotel for the Dinner, at which Mr. Eccles was supported by Mr. J. S. Hastie, Chairman of the Scottish Centre. It was followed by a dance in the Northern Meeting Rooms, whose ball-room we had so appreciated the previous night. The guests at the Dinner included Provost Wotherspoon, the Senior Baillie and the Town Clerk of Inverness, Mr. Lawrie, and directors or other representatives of many of the firms who so generously entertained us throughout the Meeting. The Dinner, reputedly the largest ever held in Inverness, gave the town its first taste of television, since, in best Institution style, the speeches were televised to a second dining-room, where some of the diners had necessarily to be seated.

The President, in proposing the toast of "The Royal and Ancient Burgh of Inverness," expressed the great pleasure of members and their ladies at being in the Highland capital, and thanked the Provost and all the people of Inverness for their welcome. He also thanked the Provost for the weather (though Mr. Wotherspoon had "nearly lost his stripes" that day through a shower of rain), and taught most of us a little geography, pointing out that Inverness is the county town of Britain's second-largest county and lies farther north than Moscow. The last chilling information seemed only to emphasize the geniality of the Highland summer.

In his reply Provost Wotherspoon first recalled some very pleasant memories which he had of Mr. Tom Johnston, Chairman of the Hydro-Electric Board, who was to his regret unable to be with us in Inverness; he and Mr. Wotherspoon were at one time respectively Chairman and Vice-Chairman of the Scottish Tourist Board. He then struck a more serious note, pointing out that, although the Hydro-Electric Board had infused a new blood stream into the Highlands, this had not yet resulted in as much increase in population and industry as local people would like. He told us that 200 empty ships leave Inverness harbour every year and appealed strongly to anyone having a say in the siting of a new factory—"Just you come and give us a trial." Nevertheless the Provost was enthusiastic about the work of the Board and stressed the care that they were taking not to disfigure the Highlands, citing Glen Affric as an example of a valley that had been actually improved by the engineering work in it. It was rather surprising, in contrast, to learn from the Provost that there were still a few crofters who were really suspicious of

* The sudden death of Mr. Lawrie on the 13th August, 1955, has greatly grieved his many friends, colleagues and acquaintances, and in particular those who met him for the first time on the Summer Meeting. All who were in Inverness and many other members of The Institution will wish to join in sending sincere sympathy to his widow and family. Apart from this footnote, the references to his great part in the Summer Meeting in this account have been left as they were originally written.

The President with Mr. L. W. Phillips, Mr. G. Parr and Mr. D. N. Relf

the Board's activities; such people, believing that Nature would reassert herself in the end, would not live on the downstream side of a dam.

The toast to the Guests was proposed by Mr. Hastie, who ingeniously included most of their names in some rhyming couplets of his own composition. He mentioned the sorrow of the Scottish Centre at the cancellation of the trip to Skye and drew our attention to the very fine coat of arms of The Institution (Scottish style) that had been painted by Mr. de Villiers' son; this was adorning a wall of the hall, instead of, alas, the front of the locomotive of the special train.

Mr. Lawrie responded in a charming speech, in which he told us, *inter alia*, that his family had long been connected with Inverness. He affirmed that "the wealth of the Highlands is at last being harnessed," and replied to Provost Wotherspoon by emphasizing the improvement in agriculture and the control of flooding from the Board's work—agriculture, "the oldest and greatest industry in the world." Mr. Lawrie also mentioned the impact of the nuclear power station programme on the Board's plans, stressing the merits of pumped storage, but adroitly confounding those who feel that hydro-electric projects are now superfluous by remarking that the Board is at present selling energy to Dounreay.

During the excellent dance after dinner, Mr. and Mrs. Eccles were presented by Mr. and Mrs. Hastie on behalf of the Scottish Centre with a silver quaich (a Scottish drinking-cup) and a Cairngorm brooch respectively. The President, though an Ulster man, seemed just as much at home in telling us how to use quaiches correctly as he was in pouring out a measure of whisky for the piper at dinner to lower in one draught.

But for the railway strike, Friday would have seen the event which, perhaps, many of us were anticipating with more eagerness than any other—the all-day railway trip to Skye along the fascinating single-line to Kyle of Lochalsh. This had been delightfully and generously organized by the three Scottish firms of Bruce Peebles, Harland Engineering and Scottish Cables. Lunch and dinner would have been served on the special train. The menus of these had been beautifully planned, and although uncooked and uneaten are too good to be left entirely out of this record. They included Thrapple Ticklers, Salmon New Drawn frae the Tay wi' Achnasheen Sauce, Mauchline Tatties, Salads frae a' the Airts, Chinterin' Chairlie, Kyleakin Scampies wi' Raasay Sauce, Wee Roastit Scotch Pullets wi' Lochluichart Sauce, Auld Reekie Trifle wi' Whuppet Cream, Breacheagh is Grouch, and Coffee frae ower the Sea.

Tantalizing they are, if not completely intelligible to a Sassenach. All old scores with railway dining cars would surely have been paid on Friday, June 10th. It must be hoped that, when The Institution again visits Inverness in 19*XX*, the Skye railway trip can be made, complete with lunch and dinner in the recorded forms.

But, of course, the refreshment was not all, and we were sorry to miss a day that promised both grand and entrancing scenery, with a wee power station slipped in for those whose technical appetites could not easily be quieted for more than half a day.

One must gratefully record that our three host firms with great generosity arranged excellent substitute programmes: an all-day excursion to the North-West, with lunch at Ullapool, or lunch in Inverness followed by afternoon excursions to the Falls of Rogie or to Grantown-on-Spey, rounded off by an evening meal and entertainment in Inverness.

The journey across Scotland to the Atlantic seaboard at Ullapool, with rhododendra in full bloom and the sea looking, in the blazing sunshine, almost unbelievably blue, was one that will be long remembered. After lunch at Ullapool, the party returned by an alternative route through Bonar Bridge. Part of the road required skilful manipulation by the coach drivers—at one particularly tricky and narrow bridge passengers had to dismount, before the drivers, in spite of urgent and conflicting advice given them by a score of engineers, managed to negotiate the obstacle.

The Inverness lunch was gargantuan; each guest had not only a complete pullet to manipulate but also an impressive helping of the ubiquitous salmon, followed by strawberries and cream and many other incidentals. The Falls of Rogie were duly approached after lunch, but the expedition was informed that the steep path and primitive bridge leading to the Falls were not in a fit state to cope with so large a party. The converse was probably truer, for the lunch had been very good.

The evening meal, which all on the meeting enjoyed, was

also very good. This, like the lunch, took place at the Caledonian Hotel, which, considering that there had been a complete change of staff only a week before our arrival, was coping magnificently with our exuberant demands from Tuesday to Friday. Lest it should be thought that the present writer had temporarily imagined he was reporting on a practical meeting of the Society for Gastronomic Appreciation, a veil will be drawn over Friday evening's programme; suffice it to say that corks from Rheims popped freely, tobacco from Havana glowed enthusiastically, we were introduced to Caledonian cabaret, and the evening ended for the third night running in a friendly mêlée of Scottish Country, and other, dancing. During the evening, Mr. and Mrs. de Villiers were presented by Mr. and Mrs. Eccles with a handsome cigarette box to the accompaniment of great applause. We departed for the 20 hotels in the late hours of Friday or the early ones of Saturday feeling that, whatever the vagaries of the railways, one of the best holes on our Inverness round had been the 19th.

Some Impressions

Perhaps the strongest impression of the 1955 Summer Meeting is one of friendliness and goodwill. This is no doubt true of many Institution meetings, but in Inverness, as on other Summer Meetings, tongues were loosened between strangers, perhaps specialists in completely different sides of electrical engineering, in a way that is unlikely to happen on Victoria Embankment. The Meeting badge—only perhaps indirectly useful for establishing another person's name through the number it bore—was a talisman to conversation in unexpected places. The Meeting did in fact present a microcosm of The Institution with a corporate spirit that ran across divisions of age or interest; it was a cogent, and far from silent, testimony to the unity of the profession.

Mr. R. L. Stanley announcing the departures of the day's excursions

Again there was no doubt that Inverness was glad to see us. Probably we formed the largest organized invasion that the burgh has experienced since the days before Culloden, when Prince Charles's army occupied the town. From Tuesday to Saturday not only the Caledonian but all the hotels did their best to make us comfortable despite the usual flow of tourists and a gnawing shortage of staff.* The Provost's welcome at the Civic Reception was a personal one that showed he was really glad to see us all. When we obey the instructions "Greas Ort Air Ais" (Haste ye back), which appears on the back cover of the Meeting booklet, as we were indeed exhorted to on several occasions, we shall be quite certain of the warmth of the Highland welcome.

There are many engaging memories of Inverness and its surroundings in a spell of bright weather that brought warmth into the sombre stone composing most of the town's buildings. Some of these are: the long, light summer evenings that refused to accept night's advances and met us with surprising sweetness on leaving the Northern Meeting Rooms after midnight; the simple beauty of the River Ness lazily finding its way through the town to the Inverness Firth beneath a sequence of graceful suspension bridges; the dappled light on the gorse, the trees and the peat of the surrounding hills; the exciting gorges in glens such as Affric, with their clean-washed stones forming uneasy beds for the streams that were thirsty after weeks of drought; the unexpected harmony of dam or power station with its surroundings; the Luichart station near Torr Achilty in the Conon Valley where the deep-cream stone from Tain is left in its natural state on the inside—it was said that the control engineers should chant a

Mr. T. R. Scott, Mr. S. E. Goodall, the late Mr. T. Lawrie, Mr. C. E. Prockter, and Mr. M. H. Beattie outside the Glen Affric Hotel, Cannich, where tea was kindly provided by the J. L. Eve Construction Co.

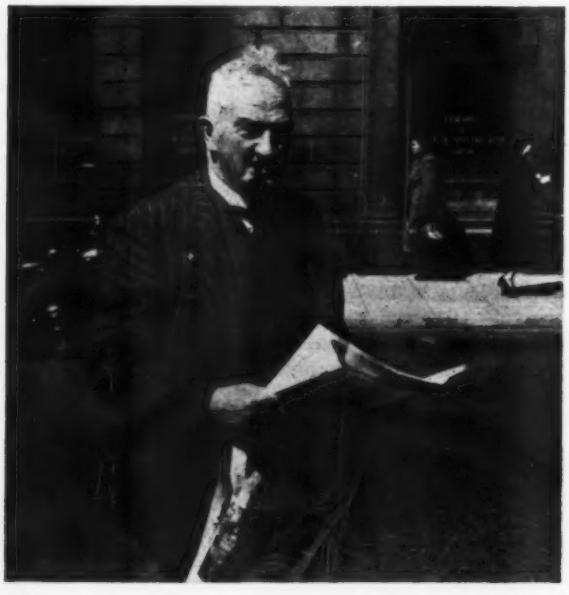
* On the return southwards someone claimed to have seen the same waitress at Inverness for breakfast, at Pitlochry for lunch, and at Gleneagles for tea, but the notion that Commodore de Villiers had a supply ship voyaging in the wake of his fleet was not proven.

psalm at the end of each shift; the scene in the Torr Achilty station with one of its 8 MVA sets yet under construction; the remarkable and successful effort at the same place to convert a contractors' hut into a gay café, where we were invited to tea by the Metropolitan-Vickers Electrical Co.; the view from Loch Benevean in Glen Affric of mountain peak after peak; the Ceannacroc Underground Station, cut out of the rock 300 feet beneath Glen Moriston, whose name gave some London visitors a momentary touch of nostalgia; the fantastic jet of water in the tail race at Fasnakyle station when a load of 10 MW was suddenly cut off one of the generators; the Trief cement made from wet slag for the Cluanie dam at the head of Glen Moriston; the smack of over-proof unmatured malt whisky on the tongue during a tour of the distillery; the hymn tunes at 6 p.m. on Inverness Cathedral bells; the excellence of Scotch salmon (though, surprisingly, in at least one hotel there were no oatcakes); the majestic loveliness of the amphitheatre into which tumble the exhilarating Falls of Foyers ("Prone down the rock the whitening sheet descends," Burns wrote of a visit in 1787; the peaty water still turns from a lazy brown to a brilliant crystal as it falls); a glimpse of Highland deer in the Conon Valley; and, not least, the admirably informative booklet for the Meeting produced by the Scottish Centre.

Above all, the Meeting's success hinged on the co-operation of the Hydro-Electric Board, and this we had in more than full measure. Their interest, their willingness to show us any of their handiwork we fancied and their hospitality were boundless. Paradoxically, their only shortcoming was lack of water,* for the Spring had been unusually dry, and some of the stations were operating at well below their maximum outputs. No one at the Meeting was concerned about

* A member who had some initial difficulty in obtaining a glass of water for a lady at one of the dams was heard to remark: "You'd think they'd still have a little to spare!"

Mr. J. M. Donaldson, Honorary Member



Waiting for the coach after lunch at Elgin

remedying this situation before the Saturday afternoon. A very pleasant feature was the presence throughout the Meeting of Mr. Lawrie. His introductory talk and film show were a model of how to instruct and entertain 200 slightly tired electrical engineers and their ladies. In addition, some ten engineers from the Board were with us to guide the daily parties of visitors and answer the numerous questions—technical and topographical—which we showered upon them. Their knowledge of the hydro-electric installations we expected; their knowledge of half a dozen other local activities from fishing to forestry and back again to fishing came as a surprise.

But, of course, the Board and its staff, as Mr. Lawrie put it, "dream of salmon." The fish lifts at the dams, the salmon hatcheries for artificial breeding, the laws for anglers posted in the power stations, the hushed respect with which local engineers speak of the salmon's habits and requirements, all bear witness to the victory of the king of fish over technologists, and the regal attention he receives from the Board.

> Oh! never fly conceals a hook,
> Fish say, in the Eternal Brook.

And though it is doubtful whether Rupert Brooke knew much about hydro-electric projects, were he alive to-day he would surely have included a Borland fish lift in the salmon rivers of his fishy heaven.

The Board are reputedly enabling the salmon, through breeding him artificially, to more than hold his own in his battle with anglers and nets; may they succeed in reducing his price to the housewife, who will then really appreciate that electricity brings cheaper living.

Return to the Lowlands

Although the entertainment of the previous night had exceeded its time limit by 2½ hours, a delicious summer morning tempted us to rise in time to be outside the Caledonian on the Saturday by 8.45 a.m., the official starting-time for our return; all except the inmates of one hotel who failed to be picked up in time—a slip which led to a cascade of frenzied

questions and answers on the coaches' loudspeakers. However, soon after 9 a.m. we were away, bound for Pitlochry by the main road that winds and unwinds, climbs and dips through fine Grampian scenery, though some of it is unhappily spoilt by the havoc in the forests that the gale of 2½ years ago has wreaked. The Cairngorms, some of whose northern gullies carry snow through the hottest summer, sparkled defiance at us as we sped down Strathspey to Kingussie and Newtonmore, where we drank coffee at the kind invitation of Reyrolle Ltd. Then on through Dalwhinnie, Glen Garry (a second one) and the Passes of Drumochter and Killiecrankie—was someone humming "Bonnie Dundee"?—to Pitlochry, where we arrived a little behind schedule. Nevertheless there was sufficient time for us to have a quick look at either Clunie or Pitlochry power station, the party splitting into two groups. The Pitlochry station is built as one structure with a dam across the River Tummel, the Kaplan turbines operating under a head of about 45 feet. The dam is used as a regulator of the level of the river in its lower reaches, by compensating for variable flow through the power stations upstream, such as those at Clunie and Errochty.

But the most attractive feature of the Pitlochry structure is probably the elaborate pool type of fish pass, in which a glass window is fitted to allow the salmon coming upstream to be watched. The fish may ascend the chain of pools in any time from one hour to a fortnight according to their age and eagerness to reach the spawning grounds; the number of fish making the passage is recorded electronically and totals about 5 000 per year. We were lucky on June 11th, since there were several unhurried medium-size salmon to be seen through the window.

Lunch at Pitlochry was kindly provided for us at three hotels by the British Thomson-Houston Co. At the Atholl Palace—an imposing grey stone structure standing in the superb grounds appropriate to a Victorian hydro—Mr. W. S. Steel welcomed us all on behalf of the Company, and the President wittily expressed our thanks, saying in the course of his remarks that the electrical industry is a very friendly one and its members enjoyed "eating each other's profits."

On from Pitlochry southwards, but the excellence of the lunch had made the present writer sleepy and although he

Mr. and Mrs. G. Lyon listen to the pipes at Cannich

recollects the tower of Dunkeld cathedral he is not clear whether he saw Birnam Woods. By Crieff he was more awake, and here in this clean little town on the doorstep of the Highlands one coach left the fleet without orders, to drop a member and his wife at the Strathearn Hydro. Although this coach had some difficulty in extricating itself from the drive of the hotel, to the entertainment of some venerable residents, the driver used his accelerator to such good effect that the coach was with the rest of the fleet by the time it reached Gleneagles Hydro some 10 miles away, and he incurred no reprimand from the flag-car. (In passing, we were so well instructed and entertained by the "Hydro-Board," that one inevitably feels that the Board are well fitted, not only by name, to add the running of some of Scotland's large hotels to their non-electrical pursuits.)

The late Mr. T. Lawrie talking to Mr. W. S. Steel outside the Atholl Palace Hotel, Pitlochry

Tea in the splendid ball-room of Gleneagles Hotel was the final combined function of the Meeting, and in thanking our kind hosts, Glenfield and Kennedy Ltd., the President made the last of his many charming "Thank you" speeches.

We had time afterwards for a short stroll on the superb lawns, and when we were back in the coaches, Mr. Eccles came and separately wished each coach load of members and ladies good-bye and a safe journey home. Then the coaches went their own ways—some to Glasgow and some to Edinburgh, where we dispersed.

Envoi

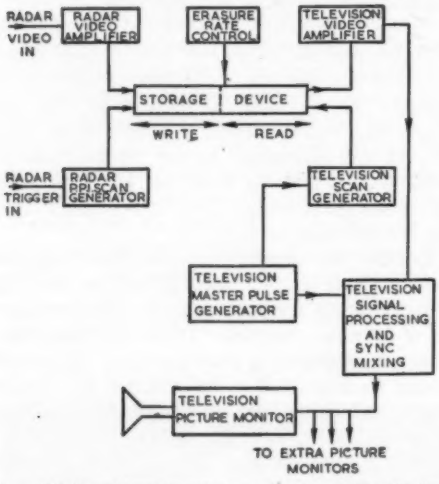
The Summer Meeting had ended, but we who were on it will long have recollections of good fellowship, delightful and instructive tours, excellent refreshment and entertainment, native hospitality, and five days of admirable Scottish weather while most of England was suffering from continual rain. We shall remember as well a friendly town—and we shall feel that we must at all costs return one day. Finally, we shall not easily forget the message of the Provost of Inverness at the President's Dinner. For here is food for reflection. We may, or may not, be worried about the depopulation of the Highlands, which has been going on for two centuries, but if we ever have control over the siting of new industry, we ought at least not to ignore the claims of Inverness.

[The Editor is indebted to Mr. E. O. Taylor, B.Sc., Member, for some passages in the above article, and to Mr. J. R. Rylands, M.Sc., Member, for most of the photographic illustrations.]

Half-Tone Storage Tubes

A DIGEST OF A RADIO SECTION PAPER (No. 1883) ENTITLED "SOME HALF-TONE CHARGE STORAGE TUBES," BY R. S. WEBLEY, B.SC., H. G. LUBSZYNSKI, DR.ING., F.INST.P., AND J. A. LODGE, B.SC., GRADUATE. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

FOUR CHARGE STORAGE TUBES which were developed in the course of an investigation into the provision of a very bright radar display are described in the paper. Conventional displays rely upon the afterglow of a cathode-ray-tube phosphor to provide the map-like presentation of the p.p.i. In the system investigated (Fig. 1) the radar



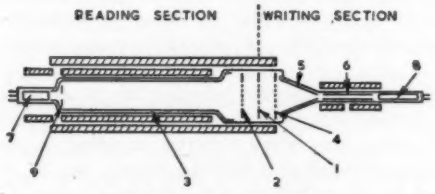
1 *Block schematic of storage-tube radar display system*

picture, which appears at a repetition rate of from 1 to 50 per minute, is written into the storage tube and read out at a much higher rate. The final display is then flicker-free, even with a phosphor of very short afterglow, and adequate mean brightness is obtained with a lower peak screen loading than is necessary in a conventional p.p.i. radar tube.

Two of the tubes described were tested on actual radar signals. The first was a photoconductive television-camera tube having a continuous layer of solid, amorphous antimony trisulphide. The radar picture was generated on the face of a bright short-afterglow cathode-ray tube and projected upon the sensitive surface. Because of the high quantum efficiency and lag of the photoconductive effect, very many pictures can be read out for a single writing operation, and in practice, when the reading raster is operated at 25 fields/sec interlaced 2:1, selected tubes will enable reading to continue for several minutes.

The overall system has good resolution, 700 separate spots in the picture diameter being possible. The background level of the final picture is also reasonably uniform. The time for which any stored picture may be read is controllable over a 3:1 range by means of variable background illumination which affects the discharging efficiency of the reading beam. Thus the tubes previously mentioned are controllable to give reading times of roughly 1–3 min. Tubes have been made with differently processed layers so that a total range from 20 sec to 3 min may be covered. All these tubes are also capable of half-tone reproduction. When projecting a line test chart on to the target, a limiting resolution of 2 000 lines is obtained.

The second of the storage tubes (Fig. 2) operates on



2 *Beam-modulation tube VCRX350*

1. Storage mesh.
2. Ion-trap mesh.
3, 5 and 6. Wall anodes.
4. Erasure mesh.
7. Reading gun.
8. Writing gun.
9. Writing-beam interceptor

a different principle, in that signals are derived from the stored charge by a modulating effect rather than by discharge. Consequently, the period for which continuous reading of a stored picture may be carried out is considerably greater than with the photoconductive tube; about 30 min for a high-definition picture, and 2–3 hours for a picture of 200-line definition have been achieved. The storage target in this tube consists of a metal mesh 1, coated on the side facing the writing gun with an insulating layer. A fraction of the beam from the reading gun passes through the mesh, the fraction being determined by the potential of the insulator in the immediate vicinity of the scanning spot. Most of the remaining reading-beam current returns to the gun 7, from which output signals are taken. Of the reading-beam electrons which pass through the storage mesh, a proportion, controllable by varying the potential of the erasure mesh 4, are reflected onto the insulating layer. The reflected electrons discharge the stored pattern, and provide control of the erasure time from about 3 sec to 30 min. The backgrounds in the experimental tubes are fair, and good backgrounds may be expected in tubes made on a production scale.

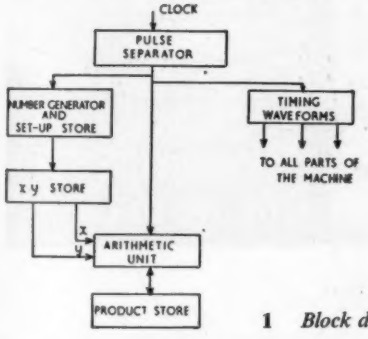
The maximum output signal is about 30 dB above amplifier noise, and a half-tone picture capable of producing this output may be written into the tube in $\frac{1}{8}$ sec. Present investigations indicate that this time may be improved in the near future. The relation between output signal and primary writing charge is roughly linear over a range of 25–30 dB. Correction of the applied signals is thus necessary if an overall gamma of unity is required.

Transistors in Computers

A DIGEST OF A RADIO SECTION PAPER (No. 1858) ENTITLED "A TRANSISTOR DIGITAL FAST MULTIPLIER WITH MAGNETOSTRICTIVE STORAGE," BY G. B. B. CHAPLIN, M.SC., PH.D., GRADUATE, R. E. HAYES, B.SC., STUDENT, AND A. R. OWENS, B.SC., GRADUATE. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

THE USE OF TRANSISTORS in computer-type circuits has been described in previous publications but little evidence has been available on the performance of such circuits when interconnected and incorporated in larger units.

A new form of digital fast multiplier operating at a basic frequency of 125 kc/s has been designed and constructed for the purpose of investigating the operation of these circuits when built into a larger system. A block diagram of the multiplier is shown in Fig. 1.



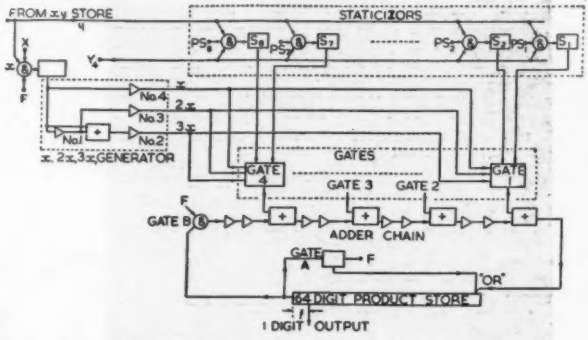
1 *Block diagram of multiplier*

In order to render the multiplier completely self-contained, storage facilities are provided which are used to set up numbers and thus simulate inputs from a hypothetical large-scale computer; they are also used to store the final answer and act as an accumulator during the actual multiplication cycle. Magnetostrictive delay lines are used in the stores, and transistors have been successfully applied to drive them.

To achieve a saving in the amount of equipment required, multiplication of two 32-digit serial binary numbers is performed in four stages. One number, y, is split into four blocks of eight digits each, which are then successively multiplied by the other number, x, in four operations, the partial products being added together to give the final product. In this way the amount of equipment is quartered, but the operation takes four times as long.

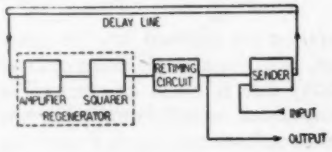
The selection of the appropriate block of digits at each stage is carried out by means of an extra 8-digit delay which is inserted into the xy store when the number is circulating. This retards the number in time with respect to the multiplier cycle, and so brings a different portion of the number into a position where it may be selected during each quarter of the complete operation.

The arithmetic unit, which is the heart of the multiplier, is shown in Fig. 2. At the top of the diagram are



2 *Arithmetic unit*

eight staticizors, S_1 to S_8, which are initially set up to conform to the first quarter of y. Each pair of staticizors controls one of four gates in the centre of the diagram and each gate has four inputs, 0, x, $2x$ and $3x$. Each gate thus selects one of its four inputs according to the particular configuration of its pair of controlling staticizors. The output from each gate is then combined in the adder chain, which consists of four adders separated by two-digit delays. The resulting partial product is delayed in the product store and emerges therefrom in time to be added to the next partial product, which results from the next quarter of y being multiplied by x. After four such operations the multiplication is complete; gate B is closed and gate A opened and the final product thus allowed to circulate in the product store. The numbers $2x$ and $3x$ are generated from x by the adder and delay stages on the left of the diagram, and this

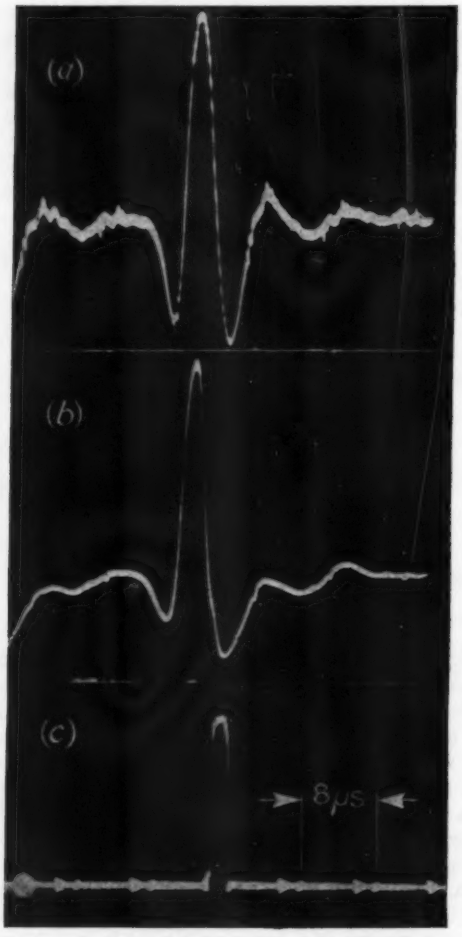


3 *Magnetostrictive delay-line store*

system enables the number of adders in the adder chain to be reduced from the eight normally required in a conventional fast multiplier to four.

The adders are of the logical type with three transistors, but the pulse-separator stages, delay stages and gates each have one transistor only.

A block diagram of one of the stores is shown in Fig. 3.



4 *Oscillograms of a single pulse in the store*

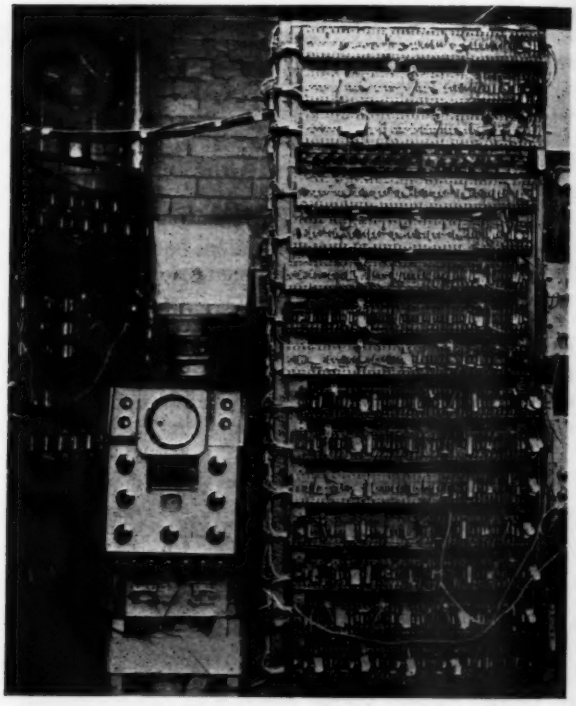
(*a*) Amplifier input. (*c*) Sender output.
(*b*) Amplifier output.
Amplitudes are not to same scale.

Pulses of 3 microsec duration are inserted into the delay line by the sending stage, which is a single point-contact trigger circuit. The delay line is made as efficient as possible by using 100 strands of nickel wire for the line itself and ferrite core pieces on both sending and receiving coils. The received signal is amplified and squared by four junction transistors and applied to a diode retiming circuit, which in turn actuates the trigger stage. Oscillograms of the regeneration of a single pulse are reproduced in Fig. 4.

The eight-digit delay which is switched into the *xy* store during multiplication is accomplished by having an extra sending coil and trigger stage on the same line. The input signal is then gated to either stage as required. The *xy* store also incorporates a "complementer," which enables the multiplier to deal with signed numbers.

In all, 96 transistors are used in the multiplier and the average power consumption is 0·5 watt per transistor. A complete multiplication, including complementing, is carried out in just over 4 millisec, of which the actual multiplying takes about 2 millisec.

Construction of the multiplier, as shown by Fig. 5,



5 *The multiplier as built*

is straightforward. The circuits are mounted on tag boards on the Post Office rack shown on the right of the Figure and the stores are mounted on the rack on the left. No attempt has been made to miniaturize the equipment. Reliability has proved to be good, only three transistors having failed in seven months of daily operation.

It is concluded that at repetition frequencies up to 100 or 200 kc/s the point-contact transistor has several advantages over the thermionic valve as a computer element. Its small size and low-power requirements simplify construction, and the low output impedance of the point-contact-transistor regenerative amplifier facilitates the interconnection of circuits and lends itself to unit construction.

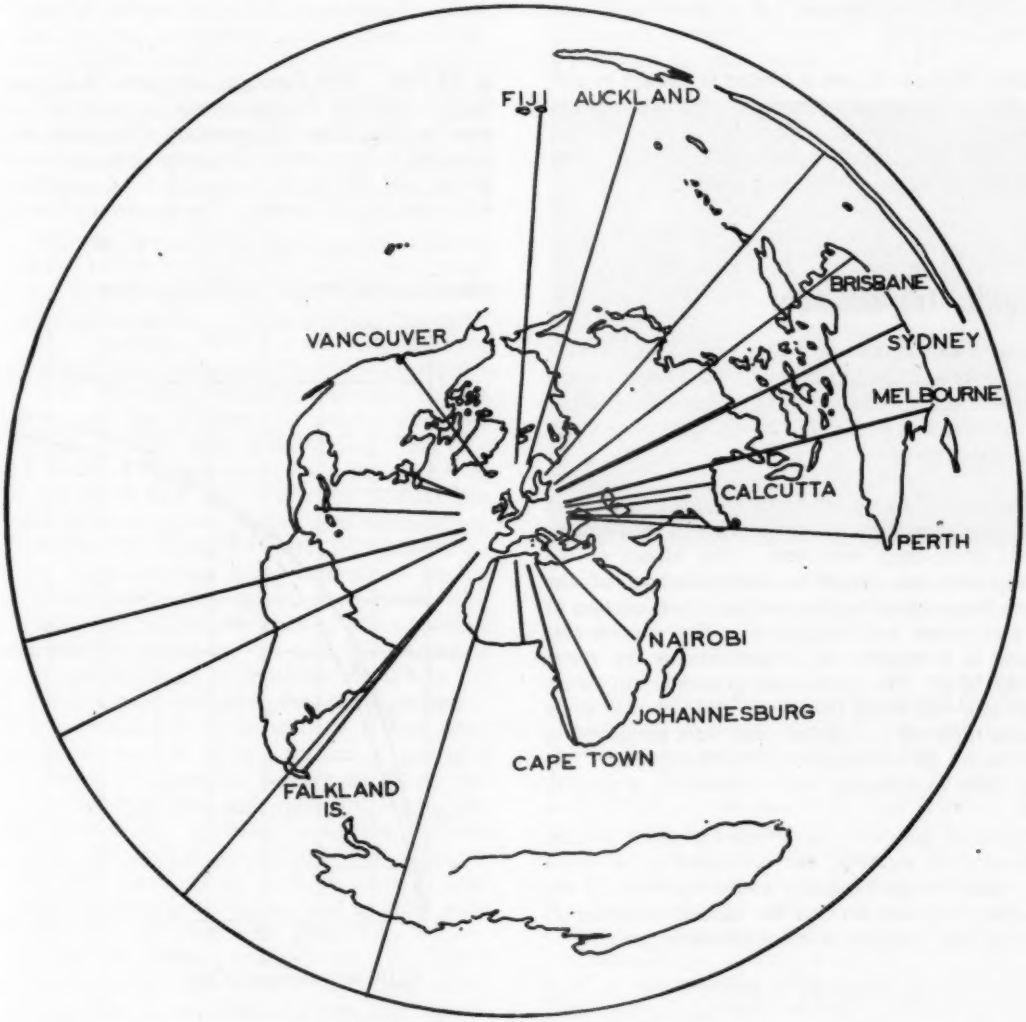
An Ionospheric Chart

A DIGEST OF A RADIO SECTION PAPER (No. 1855) ENTITLED "AN IMPROVED CHART FOR IONOSPHERIC FORECASTING IN THE BRITISH ZONE," BY R. NAISMITH, MEMBER. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

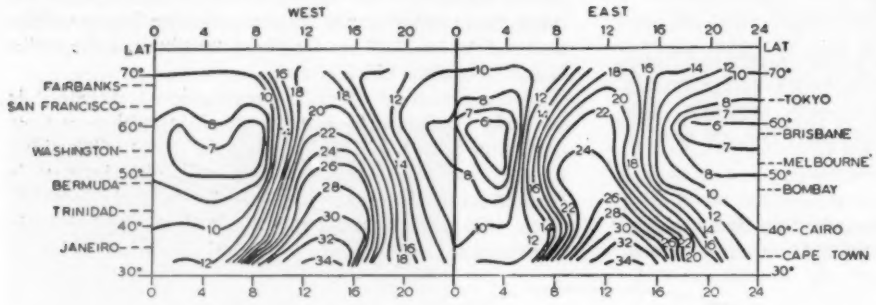
THE IMPORTANCE of radio communication as an aid to the life and progress of the British Commonwealth of Nations is often underestimated and sometimes overlooked. The map (Fig. 1) shows, on a gnomonic projection centred on London, that the United Kingdom is more or less in the centre of the land (populated) area and that it is necessary therefore to be able to communicate in all directions. This involves a knowledge of the ionospheric conditions at the point of reflection (generally assumed to be 2000 km from the terminal) if the radio link is to operate efficiently.

In the provision of radio propagation forecasts it is generally necessary to provide the information in four dimensions, latitude, longitude, frequency and time. In the case in question, where particular interest is focused on specific points on the periphery of the 2000 km circle, it is possible to combine the latitude and longitude dimensions and to provide the variable dimensions of frequency and time (referred to individual points) on one composite chart.

The British Zone chart (Fig. 2), which has been prepared on this basis, in addition to providing the forecast information over a continuous time-and-frequency scale



1 *United-Kingdom–Commonwealth radio routes*



2 *British Zone chart*

is also direct-reading. Its use is limited to circuits to and from the United Kingdom at the times at which they are controlled by ionospheric conditions at the United Kingdom end. It is equally applicable to circuits from the United Kingdom to other places abroad.

Waveguide Impedance

A DIGEST OF A RADIO SECTION PAPER (No. 1882) ENTITLED "ON THE SURFACE IMPEDANCE OF A CORRUGATED WAVEGUIDE," BY A. E. KARBOWIAK, B.SC.(ENG.), PH.D. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

IN A RECENT PAPER* a series of experiments on cylindrical surface waves supported by corrugated $\frac{3}{16}$ in diameter brass rods have been described. The object of the experiments was an empirical determination of the surface reactance of corrugated surfaces as a function of surface parameters and frequency. The experiments were made at a number of frequencies in the range 2 500–10 000 Mc/s. The guides were grooved transversely at regular intervals along the length, and although some three dozen different corrugated rods were employed in the experiments, all corrugations were rectangular. The results of these experiments were recorded in a number of graphs.

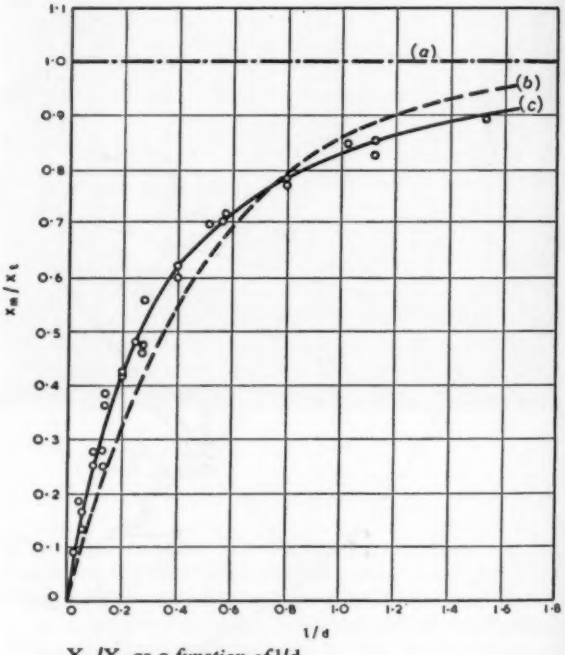
In the present paper it is observed that these results, when normalized suitably, are contained in a single formula, whatever the frequency and proportions of the corrugations. It is shown that the surface reactance X_s of a surface with rectangular corrugations is given by

$$X_s = X_{slot}\left(\frac{d}{D}\right) f\left(\frac{l}{d}\right) \quad . \quad . \quad . \quad . \quad (1)$$

where l is the depth of corrugation;
D is the pitch of corrugation;
d is the width of the corrugation slot;
and the function X_{slot} depends on frequency, guide radius and corrugation depth, while $f(l/d)$ is a function of l/d only. Both functions are given in the paper and hence, using eqn. (1), the surface reactance of any corrugated surface, given the necessary dimensions of the surface, can be calculated. The graph below shows the plot [curve (*c*)] of X_s/X_t where $X_t = X_{slot}(d/D)$ together with experimental points. The equation of curve (*c*) is

$$f(l/d) = 1 - \tfrac{1}{2}\varepsilon^{-5l/d} - \tfrac{1}{2}\varepsilon^{-l/d} \quad . \quad . \quad . \quad (2)$$

where ε is the base of natural logarithms.



X_m/X_t *as a function of* l/d

Curve (*b*), which is already a good approximation to the experimental points, has the equation

$$f(l/d) = 1 - \varepsilon^{-2l/d}$$

and curve (*a*) is an approximation valid only for deep corrugations ($l \gg d$), and is the plot of the theoretical expression derived previously by Barlow and Karbowiak.

* BARLOW, H. E. M., and KARBOWIAK, A. E.: "An Experimental Investigation of the Properties of Corrugated Cylindrical Surface Waveguides," *Proceedings I.E.E.*, Paper No. 1625 R, May 1954 (101, Part III, p. 182).

Electrolytic Cleaning and Polishing

A DIGEST OF A UTILIZATION SECTION PAPER (No. 1866) ENTITLED "ELECTROLYTIC PROCESSES FOR SURFACE CONDITIONING OF METALS," BY PROFESSOR J. W. CUTHBERTSON, D.SC., ASSOCIATE MEMBER. THE FULL PAPER WILL BE PUBLISHED IN PART A OF THE PROCEEDINGS

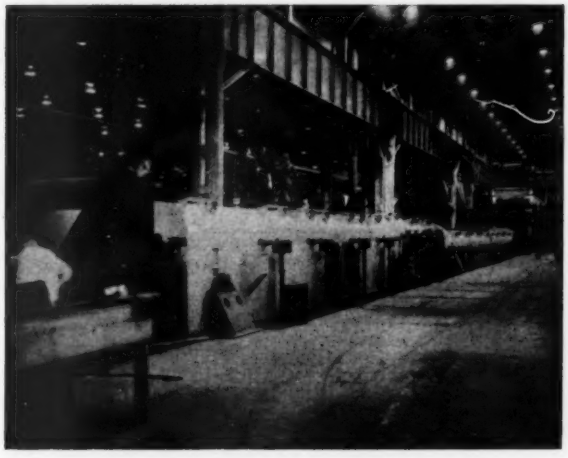
ELECTRO-DEPOSITION is an important part of many production processes. Before a metal or alloy can be satisfactorily coated with another by electro-deposition, pre-treatment of the base material is necessary to render it clean and perhaps to provide it with some specific finish to increase the adhesion of the deposit. Electrolytic processes are widely used in the sequence of plating pre-treatment operations. Broadly speaking, these operations fall into two categories: (*a*) cleaning, and (*b*) etching. Cleaning is frequently, but not invariably, a cathodic process; etching is essentially anodic in character.

In the early development of electroplating, cleaning was carried out by solvent degreasing, and scale or oxide was removed by direct pickling in acid. Such processes are still extensively employed; they are indeed frequently essential, but advantages accrue from supplementing them with and in some cases replacing them by electrolytic processes. These advantages can perhaps best be appreciated if one first considers the general principles of electrolysis. When a solution containing a salt of a metal such as nickel is electrolysed, by using a sheet of nickel for the anode and, say, a sheet of steel for the cathode, nickel dissolves from the anode into the solution and a corresponding amount of metal is deposited on the cathode, these amounts being determined by the quantity of electricity flowing in accordance with Faraday's laws and by the efficiency of the respective anodic and cathodic processes. If, now, the electrolyte contains no metal that can be deposited, i.e. if it is, for instance, a solution of sodium hydroxide or sulphuric acid, the ion discharged at the cathode is hydrogen. This gas, in its nascent form, exercises a powerful scavenging action, the liberated bubbles disrupting and loosening any adherent scale and oxide and leaving the underlying metal readily available to further chemical cleaning by the detergent action which is often a feature of the electrolytes used. If an insoluble metal is used for the anode, no dissolution occurs, and so there is no contamination of the electrolyte from this source. Cleaning in this way is cheap and effective. No visible damage is done to the base metal, though with some steels hydrogen can be absorbed and this may lead to embrittlement. In such cases anodic treatment is often advisable.

Cathodic cleaning is most frequently done in hot alkaline solutions. Acid solutions are sometimes preferred, however, as in the Bullard–Dunn processes, where the electrolyte contains sulphuric acid and stannous sulphate. This is really a combined descaling and cleaning process. Considerable ingenuity has been applied in mechanizing this process and in making use of rotary conveyor plant and automatic elevating gear.

Anodic pickling in acid is now extensively used to remove scale and rust from steel and to etch the surface of the steel in order to increase adhesion of the deposit. Compared with pickling without current the anodic process is susceptible to much closer control, is quicker, and can be operated at a lower temperature.

The latest development in electrolytic cleaning is alternate anodic and cathodic treatment in a single unit. Such processes are favoured for the preparation of the steel base used in the production of tinplate by the continuous electrolytic process. A typical cleaning unit is shown in the photograph.



Cleaning and pickling tanks of an electrolytic tinning line
(By courtesy of the Weirton Steel Co., West Virginia)

Another interesting use of electrolysis for the surface conditioning of metals is the anodic oxidation process for increasing corrosion resistance and for providing a decorative finish on aluminium and its alloys. These materials are almost unique in their response to anodic treatment in electrolytes. If they are made anodic in chromic, sulphuric or oxalic acid, an oxide film is produced on the surface which is much more protective than the film that is acquired naturally as a result of atmospheric oxidation. Not only does the process increase corrosion resistance, but it provides a surface finish which can be dyed to give pleasing decorative effects or made light-sensitive by impregnation with suitable silver salts and thereafter adorned by photographic methods as in conventional practice. In a recent modification of this process the hardness of the anodic film is much increased, and this development is likely to prove attractive particularly in engineering applications where a high resistance to wear and abrasion is demanded.

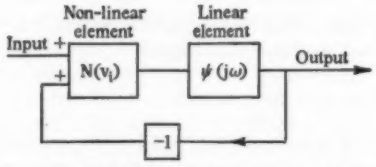
One of the most recent developments in surface conditioning is the electrolytic polishing of metals. In

this process a levelling action is secured by controlled anodic dissolution. With a suitable electrolyte and at a suitable current density elevations on the surface of a rough piece of metal can be dissolved and attack simultaneously restrained in depressions. The result is a polishing or smoothing action from which under the right conditions an excellent surface finish is obtained. Mechanical polishing is expensive, and some articles by virtue of their shape are almost impossible to polish in this way. Moreover, mechanical processes can induce stresses in the surface of a metal which lead to dimensional or metallographic changes. In the case of gas-turbine blades, for example, such effects cannot be tolerated, and the electrolytic process is therefore attractive since it produces no such ill effects. In many directions the advantages of this interesting process are being increasingly realized and considerable further expansion of its use is envisaged.

Sub-Harmonics in a Feedback System

A DIGEST OF A MEASUREMENTS SECTION PAPER (No. 1693) ENTITLED "THE MECHANISM OF SUB-HARMONIC GENERATION IN A FEEDBACK SYSTEM," BY JOHN C. WEST, B.SC., PH.D., ASSOCIATE MEMBER, AND JOHN L. DOUCE, M.SC., GRADUATE. THE FULL PAPER WAS PUBLISHED SEPARATELY IN JULY, 1954, AND IT IS REPUBLISHED IN SEPTEMBER, 1955, IN PART B OF THE PROCEEDINGS.

A FEEDBACK SYSTEM (Fig. 1) incorporating a non-linear element is analysed to consider the effect of a sinusoidal

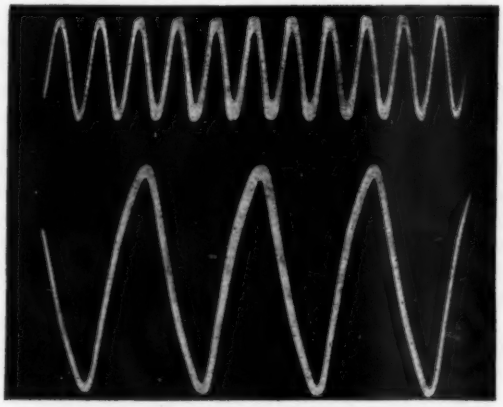


1 *Block schematic of the general system*

input. Simple non-linear theory predicts that the output will contain a fundamental component plus harmonics of this frequency. In practice, certain systems give an output whose lowest frequency is a fraction of this input frequency. This phenomenon is termed frequency de-multiplication or sub-harmonic generation.

The previous "theory" of this effect, assuming synchronization between the harmonic of the sub-harmonic and the primary input, by some indeterminate mechanism, is rejected. The explanation proposed considers the input signal as a means of modulating the gain of the non-linear element. It is shown that the gain of the non-linear element is changed in both amplitude and phase for a sine wave of frequency a fraction that of the input. This effect makes the closed feedback loop unstable, the frequency of oscillation being this fraction of the input frequency.

The cubic non-linearity is fully analysed as an example, and it is shown that the sub-harmonic of frequency one-third that of the input frequency can occur if the phase lag of the linear system lies within the range 159°–201°.



2 *Waveforms at the input and output of the system when sub-harmonic resonance occurs*
(*a*) Input. (*b*) Output.

Typical waveforms observed at the input and output of the system considered are shown in Fig. 2.

Strip-lines

A DIGEST OF A RADIO SECTION PAPER (No. 1852) ENTITLED "A DOUBLE-GROUND-PLANE STRIP-LINE SYSTEM FOR MICROWAVES," BY BENGT A. DAHLMAN. THE FULL PAPER WAS PUBLISHED IN JULY, 1955, IN PART B OF THE PROCEEDINGS.

GREAT SAVINGS in cost and space can be achieved by substituting strip-lines for waveguides and coaxial lines in microwave circuits. The paper deals with a transmission line of the shielded strip-line type, consisting of a conducting strip between two parallel conducting planes. This line has proved to be very useful as a base for microwave circuit development. Most complicated circuits can be built much more easily in strip-line than with the conventional waveguide or coaxial technique. This is true both for laboratory work and for mass production. Strip-line circuits are also much less bulky. For transmission purposes, on the other hand, the strip-line has neither the low attenuation of the waveguide nor the flexibility of the coaxial cable.

The paper is intended for the practical engineer as an introduction to the technique of the double-ground-

plane strip-line. Transmission characteristics such as phase wavelength, characteristic impedance, attenuation and power handling capacity are calculated. These calculations have been kept at a rather elementary level by several assumptions. The author has tried to point out the consequences of the assumptions and the limits for application of the formulae and curves.

Practical viewpoints on the design of strip-line circuits are given. The circuits can be manufactured by different printed-circuit methods, among which one involving etching of the circuit from a metal-clad dielectric sheet is the most promising.

Finally, a practical application of double-ground-plane strip-line circuit work is described. A rough estimation of the costs for a specified circuit shows a reduction of the order of 80% compared with those for the corresponding coaxial arrangement, whether for a single unit or for quantities.

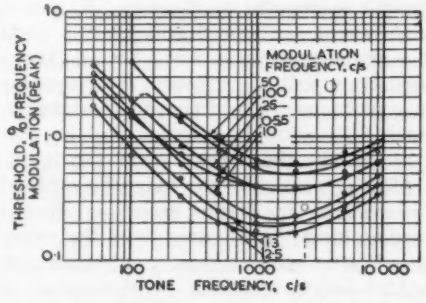
Distortion in Sound Recording

A DIGEST OF A RADIO SECTION PAPER (No. 1874) ENTITLED "THE SUBJECTIVE DISCRIMINATION OF PITCH AND AMPLITUDE FLUCTUATIONS IN RECORDING SYSTEMS," BY A. STOTT, M.A., ASSOCIATE MEMBER, AND P. E. AXON, O.B.E., M.SC., PH.D., ASSOCIATE MEMBER. THE FULL PAPER IS PUBLISHED IN SEPTEMBER, 1955, IN PART B OF THE PROCEEDINGS.

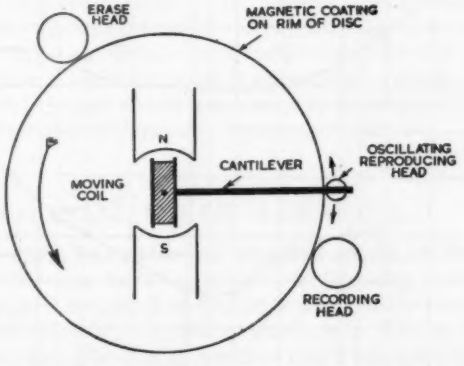
TWO TYPES OF DISTORTION which occur in the process of recording and reproducing sound are the introduction of small fluctuations of pitch and amplitude which were not present in the original sound. These arise from imperfections in the recording machine, the reproducing machine and the recording medium. In the course of an investigation controlled pitch and amplitude fluctuations were generated in tones, musical programmes and speech, in order to determine the sensitivity of the listener to such conditions. The human ear is known to display a complex variation of sensitivity, or *threshold of detection*, to these fluctuations, depending on their frequency and amplitude.

In all systems of sound recording the recording medium is first driven past a transducer which effects changes in the medium representative of the frequency and amplitude variations in the sound being recorded. In the subsequent reproducing process the medium is driven past another transducer which produces a signal representative of the changes previously effected in the recording medium. The fidelity of this reproduced signal at any given point in the recording depends on the properties of the two transducers and the recording medium. It also depends on the relative speeds of the recording medium in the recording and reproducing processes at this point. An unwanted pitch fluctuation (or frequency modulation) occurs always as a result of an accidental difference in these two speeds. In practice the unwanted speed changes are usually a mixture of regular and random components, the former arising from eccentricities, or similar defects, in the mechanical elements, whilst the latter are due to frictional and other irregular changes.

The sensitivity of the ear to pitch fluctuations in steady tones is surprisingly high, and measurements of this threshold may be carried out using purely electronic apparatus in which the fluctuation is generated by appropriate alteration of some element in an oscillator circuit. The variation of subjective threshold with sinusoidal modulation of tone for various modulation frequencies is shown in Fig. 1. Manufacturing problems would be very great if recording apparatus had to be built to an accuracy giving fluctuations of magnitude less than the minimum detected here. Fortunately the thresholds for more usual signals, such as musical programme or speech, are higher. Practical tolerances may then be ascertained by determining the thresholds for a programme of a musical instrument, e.g. the piano, which is known to reveal the effects of accidental frequency-modulation most easily. The generation of controlled frequency fluctuations in such a programme is, however, more complicated and it can be achieved only by employing a recording method. Care is then necessary to exclude the effects of any accidental fluctua-

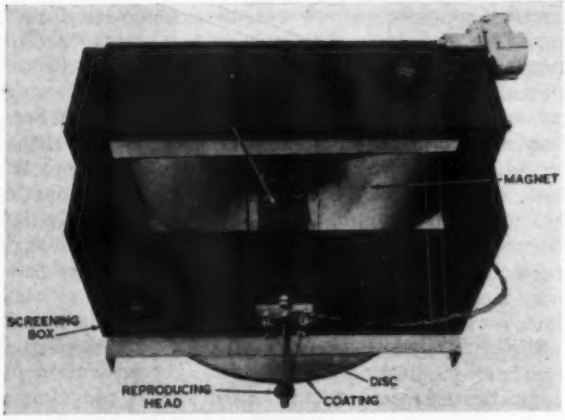


1 *Subjective threshold variations for sinusoidal frequency-modulation of tone*



2 *Sketch plan of pitch-fluctuation generator for programme-material experiments*

tions occurring in the recording system itself. Fig. 2 is a plan of a recording system which may be made to have negligible inherent fluctuations of its own but in which a wide range of controlled fluctuations may be generated. The disc, coated with a magnetic medium, rotates out-of-contact with the magnetic heads at constant speed,

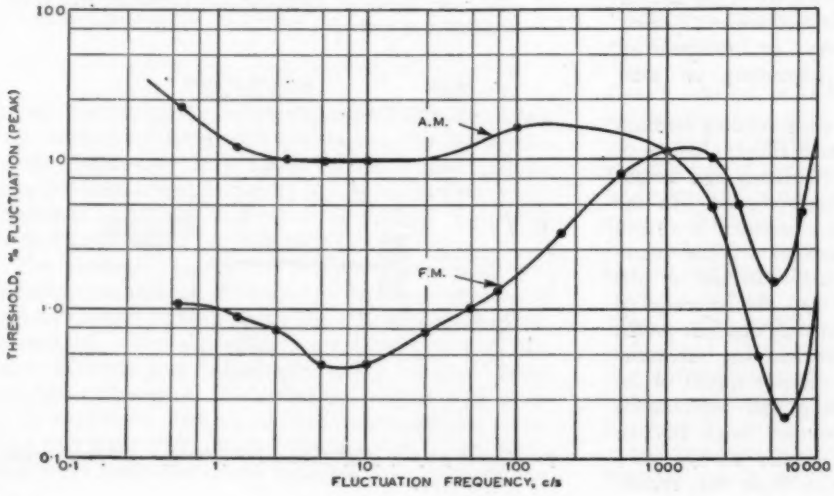


3 *Front view of pitch fluctuation generator*

and the programme is recorded on its edge. By means of a moving coil system, the reproducing head is made to move about a central position so that a known change of relative speed is introduced between the recording and reproducing processes. The frequency and amplitude of the pitch fluctuation introduced into the programme are governed by the control signal fed to the moving coil. After reproduction the magnetic medium is erased and is available for further recording when it passes the recording head. The output from the reproducing head passes, after amplification, to a loudspeaker or a pair of headphones as required. A photograph of the practical realization of the recording system is shown in Fig. 3, and the average threshold variation of a large body of listeners for sinusoidal frequency modulation of a piano programme is shown in Fig. 4.

Amplitude fluctuations (or modulations) also arise as a corollary to accidental speed changes in recording systems which are velocity-responsive. However, there are other, quite separate, causes, such as alterations of sensitivity of the recording medium or, in a tape system, variations in the effective separation between the medium and the recording and reproducing heads. For experimental purposes, amplitude fluctuations may also be generated in a programme by purely electronic means and this was the most convenient method for the present investigation. A curve showing the variation of average threshold of another body of listeners for amplitude modulation of a piano programme is given also in Fig. 4.

With this information it is possible to define standards of excellence to which recording systems must conform if distortions of the type discussed are to be imperceptible to most listeners. Any recording system can then be tested, both after manufacture and in service, with apparatus which indicates whether it conforms to these standards. A convenient method is to record and reproduce a test tone with the system and measure the accidental fluctuations which are present in the output. For a correct result the measuring chain must be weighted in a manner which takes account of the frequency variation of subjective thresholds. The ideal subjectively-weighted measuring chain should, when threshold value is reached, give the same indication whatever the type and frequency of the fluctuation occurring. To a good approximation, such an ideal chain is obtained if a frequency-weighting characteristic which is the inverse of the relevant threshold curve shown in Fig. 4 is employed in the measuring system. The measuring chain may be calibrated at a single fluctuation frequency with reference to the corresponding absolute threshold shown in the Figure.



4 *Composite curves of fluctuation thresholds (amplitude modulation and frequency modulation) for piano programme material*

OBITUARY

WALTER FREDERICK BISHOP

Walter Frederick Bishop, C.B.E., who died on the 27th April, 1955, was born on the 2nd May, 1879. The most remarkable feature of his life was the long period of service which he devoted to W. T. Henley's Telegraph Works Co., and to the whole of the cable making industry. He received his general education at the Grocers' Company School, and his engineering education at the City of London College and East London College. He joined Henley's on the 1st May, 1895, and if he had lived another three days he would have completed 60 years' service with the company.

His first appointment was as Estimating Clerk, and after experience in many departments, both at the Head Office and Works, he held successively the positions of Chief of the Estimating Department, Sales Manager and Assistant General Manager. He was appointed General Manager of the Company in 1932 and held that position for many years.

He was elected to the Board in 1933 and remained a Director until his death. He also held Directorships in Henley's (S.A.) Telegraph Works Co.; Henley's Tyre & Rubber Co.; Holborn Construction Co.; Southern United Telephone Cables (of which he was Chairman); Union Cable Co.; Electrical Facilities; Power Holdings; Settle & District Electric Supply Co., and the Henley Extrusion Machine Co.

His term of office as General Manager at Henley's included some of the most difficult years in the history of the company, during which he was associated closely with the late Chairman, Sir George Sutton. During this period his loyalty, enthusiasm and shrewdness contributed to his own personal advancement and to the progress of the firm. Although he made no claim to technical or scientific training, he had a remarkable flair for the practical. Not only did he take a keen interest in electrical developments of all kinds and in their possible application in the cable industry, but on many occasions, in discussions on production with those responsible for factory organization and control, he was able to bring out important engineering points, and his opinion was widely respected in this field.

Mr. Bishop always took a keen interest in The Institution, and served on several committees, including the Wiring Regulations Committee. He was for some time Chairman of the Cable Makers' Association. During the Second World War he was Chairman of the Cable Makers' Planning Committee of the Ministry of Supply, in which capacity he rendered outstanding service to the country in the organization of supplies and allocation of material between the requirements of the Services. For this work he was made a Commander of the British Empire in 1944.

Of recent years one of Mr. Bishop's chief interests and responsibilities was the formation and guidance of Southern United Telephone Cables Ltd., of which he was Chairman for 23 years. This company was formed as part of the rationalization of the telephone cable industry sponsored by the Post Office in 1932. Mr. Bishop's knowledge of the industry was unique and under him the company achieved considerable eminence.

Mr. Bishop, always a keen gardener, was a Liveryman of the Worshipful Company of Gardeners. He was also a Freeman of the City of London, and at one time President of the London branch of the Association of Mining Electrical Engineers.

He joined The Institution as an Associate in 1919 and was elected a Companion in 1929. P. D.

FREDERICK WILLIAM GILL

Frederick William Gill, who died on the 17th April, 1955, after a short illness, was born in Plymouth on the 15th May, 1905. He received his general education at Sutton High School, and his engineering training at the Royal Dockyard School, Devonport. After completing an apprenticeship as an Electrical Engineer in H.M. Dockyard, Devonport, he entered the Engineering Department of the Post Office as an Inspector in 1925. From 1925 to 1939 he served in various establishments of the Post Office in England and Wales, reaching the rank of Executive Engineer. In 1939 he was loaned to the Admiralty, and was engaged on naval telecommunication at home and abroad throughout the war. For some time he acted as a liaison officer between the Post Office and the Admiralty, and he served in Ceylon as an adviser on line communication. On the fall of Japan he entered Singapore with the British Naval forces, and did valuable work thereafter in restoring the communication system of the dockyard. Shortly after his return to the Post Office in 1946, he was appointed Deputy Telephone Manager in the London Telecommunications Region, a post he held until his death.

Mr. Gill was a keen swimmer and golfer and for many years a well-known figure in amateur operatic circles.

He joined The Institution as an Associate Member in 1937 and was elected a Member in 1949. G. S. B.

WILLIAM MILES HORSFALL

William Miles Horsfall, who died on the 1st December, 1954, was born in 1871. Mr. Horsfall received his general education at Repton School, and his engineering education as a premium pupil under Mr. A. Bromley Holmes, who was at that time City Electrical Engineer of Liverpool Corporation.

After three years he joined the staff of the Liverpool

Electric Supply Co. as Electrical Inspector of Installations, and after a further three years, in 1896, he was appointed Engineer and Manager of the Liverpool District Lighting Co. He held the position for 15 years and supervised the erection of the generating stations at Waterloo and Gateacre. He also carried out numerous private installations and undertook consulting work, which he continued for several years in Liverpool after his resignation from the company in 1910.

In September, 1916, Mr. Horsfall joined the Liverpool Branch of the Edison Swan Electric Co. as Chief Outside Representative. He served for 18 years with this company until 1935, when owing to ill-health he went into semi-retirement. He is survived by his widow.

He was elected a Member of The Institution in 1903.

P. L. D.

WILLIAM MARSH

William Marsh, who died in Brighton on the 26th March, 1955, after a short illness, was born on the 11th May, 1876, and was educated at the Bootham School, York; Brighton Technical School; and Glasgow and West of Scotland Technical College.

Mr. Marsh had spent about a year with the Glasgow City Tramways when he came to Brighton in 1900. He helped to plan the Brighton Corporation Tramways system, and in 1905, whilst still under 30 years of age, he was made Engineer and Manager, which position he held until his retirement in 1939. The whole of his career was occupied with transport, and he saw the tramcar progress from its infancy, through the days of its popularity, to the stage of obsolescence. Under his management the number of vehicles operated in Brighton increased from 30 to 80, all of which were built in the Corporation workshops, and during this time the design developed from the almost primitive to the modern form with high-speed motors, helical gearing, roller bearings, and pneumatic brakes. He made a close study of the problem of electrolytic action arising from leakage from tram rails, and it is noteworthy that Brighton had little, if any, trouble from this cause.

Mr. Marsh was closely interested in the development of the trolley-bus, and, the Corporation having obtained the necessary powers in 1912, an experimental vehicle was run in Brighton in 1914.

Mr. Marsh was a man of great integrity, and a deep sense of responsibility and personal attention to all matters of detail were the outstanding features of his managership. After his retirement he remained very active, and, as secretary of an important institution and having an interest in the administration of a utility business, he sometimes boasted that he worked harder than during his younger years. He owned a large and beautiful garden, of which he was very proud and which he was pleased to share with others. There are many, especially old people and children, who will remember with gratitude the festive outdoor occasions when they were the guests of Mr. and Mrs. Marsh.

His interment at the Friends' Burial Ground was followed by a well-attended memorial service at the Friends' Meeting House, Brighton. He is survived by his widow, two sons and a daughter.

He joined The Institution as an Associate in 1900, and was elected an Associate Member in 1903 and a Member in 1912.

A. B.

BENJAMIN NORTH

Benjamin North, B.Eng., who died on the 2nd April, 1955, was born on the 14th April, 1897. He was educated at Liverpool Collegiate School, served in the Army during the First World War, and then studied at Liverpool University, where he obtained a B.Eng. degree in 1922. His practical training was received at the Metropolitan-Vickers Electrical Co. from 1922 to 1925.

In 1926 Mr. North began a tour of the Far East on behalf of Metropolitan-Vickers, and was instrumental in the erection and completion of various power stations and in developing power plant schemes in places as far apart as Singapore, Calcutta and Colombo. He returned to England in 1929 for a short period of service in the General Engineering Department of the company at Trafford Park, but 1931 saw him again in Calcutta, a city he liked very much, as Construction Engineer in charge of the Cossipore power station, on which building had just started. A bachelor, he travelled extensively in India, Malaya, Singapore and the Middle East. His liking for the East led to his joining the Bengal Public Works Department, where he became Superintending Engineer. He returned to England in 1938.

The Second World War found him as a Civilian Garrison Engineer at Bulford in Southern Command in charge of electrical and mechanical design. He joined the Royal Engineers and was rapidly promoted to the rank of Major. His various staff appointments, under which he was responsible for the execution and design of electrical and mechanical installations of all kinds, took him to Egypt, Syria, Turkey, Italy and Albania.

After the war he returned to the Civil Service and continued to use his considerable electrical and mechanical knowledge to such effect that he was appointed to the post of Superintendent of Works, R.E., North Mercia, Staffordshire, in 1952. He and a colleague shared the distinction of being the only two civilians who had held the post of C.R.E.(Wks.), normally the prerogative of a serving Lieutenant-Colonel, R.E. As Superintendent at North Mercia he had to build up the organization in a newly created Area covering Staffordshire, Northern Warwickshire and the whole of Shropshire; his efforts were amply rewarded in the results he obtained. His direction and leadership endeared him to all ranks and his popularity with his staff was made evident by the extremely happy atmosphere in which its members worked.

He joined The Institution as an Associate Member in 1933 and was elected a Member in 1937. He was also an Associate Member of The Institution of Mechanical Engineers.

F. A. T.

MONOGRAPHS AND PAPERS
published separately this month

Separate monographs and reprints of all papers published in the Proceedings are available at the price of 1s. 3d. each (post free). The inclusive charge for a copy of a paper allocated for reading at a meeting on separate publication and for a reprint of the paper and discussion (as republished in the Proceedings) is 2s. 6d. (post free). This charge is made whether or not the reprint is required, but a reprint alone costs 1s. 3d. as noted above. However, separate copies of a paper allocated for reading are supplied free of charge 10 days before the first meeting at which the paper is to be read, whether in London or in the provinces. If a reprint also is required, a remittance should accompany the request. Reprints of a paper being read at a meeting cannot be issued before the paper and discussion have appeared in the Proceedings, but they should preferably be ordered before or shortly after the paper has been read in London.

In an order, a monograph or a paper can be specified completely by the author's surname and the serial number of the paper. Those who wish to avoid making a separate payment for each monograph, paper, or reprint which they require can obtain books of voucher-labels, price 10s. each, containing 8 vouchers, on application to the Secretary.

A list of papers published in the September issue of Part B of the Proceedings appears under "Contents of the Current Issues of the Proceedings" on page 619, and the serial number of each paper and the month of publication of a digest in the Journal are included. Synopses of both monographs and papers which will be published separately before the next issue of the Journal appear below, and unless otherwise stated, their date of publication is the same as this issue of the Journal. The monographs will be republished in Part C of the Proceedings, and the relevant Part for the republication of a paper is given after the serial number of the paper.

MONOGRAPHS

The Design of Quarter-Wave Matching Layers for Dielectric Surfaces

MONOGRAPH No. 149 R

R. E. COLLIN, B.Sc., Ph.D., and JOHN BROWN, M.A., Ph.D.

A quarter-wave transformer to match the junction between an empty waveguide and one completely filled with a dielectric may be made from a waveguide partially filled with dielectric. A method of designing such a transformer, when all the waveguides have the same cross-section, is described, and experimental results are given to show that this design is satisfactory. A similar arrangement can be used to match the surfaces of a dielectric lens: slots are cut on the surface and design information is given for slots parallel or perpendicular to the electric field of the wave incident on the surface. Measured reflection coefficients for a surface matched in this way are in good agreement with calculated values.

A digest of the monograph will be published in Part B of the *Proceedings*.

Electromagnetic Momentum and Electron Inertia in a Current Circuit

MONOGRAPH No. 150

PROFESSOR E. G. CULLWICK, O.B.E., M.A., D.Sc.

In the second volume of his "Treatise on Electricity and Magnetism" Clerk Maxwell developed the theory of electric current circuits from general dynamical principles, and discussed the experimental effects which should occur if an electric current is a true motion of some substance possessing inertia. Since none of these effects had at that time been observed, Maxwell developed his general electromagnetic theory on the assumption that they did not exist, or at least that they produced no sensible effect.

It is now known, however, that an electric current in a conductor consists of moving electrons, and the inertia effects which were discussed by Maxwell have been observed experimentally. They are extremely small, and have not been brought within the scope of electromagnetic theory. A conduction current is usually assumed to be due to the drifting along the conductor, with a very small mean velocity, of all the available conduction electrons, so that the kinetic energy of the electrons due to this motion is negligible in comparison with the magnetic energy of the current. Electron-inertia effects in current circuits have therefore been accepted as something outside classical electromagnetic theory—a position which is illogical if, as is usual, we identify the kinetic and magnetic energies of a free electron.

It is shown in the paper that it is possible to identify the kinetic energy of the conduction electrons in a current circuit with the magnetic energy of the current, so that electron-inertia effects can be included in the general electromagnetic scheme. In consequence, a current circuit can be said to possess an electromagnetic mass whose motion, when current flows, entails electromagnetic momentum. This momentum accounts for the known effects of electron inertia and also for the force on the end wire of a long rectangular circuit.

PAPERS

Pulse-Time-Modulation Terminals for Music Transmission over Radio Links

PAPER No. 1900 R; PART B

R. F. ROUS, B.Sc.

A communication system is described which enables three music circuits and an engineer's circuit to be combined. The combination is effected by using pulse time modulation in four time-division multiplexed channels. The purpose of the system is to enable a microwave link, intended for the transmission of television signals, to carry audio signals of broadcast-programme quality as an alternative. The radio equipment, primarily intended for television transmission, need not be specially designed for this particular service.

Measurements of the performance of the equipment indicated very satisfactory signal/noise and signal/crosstalk ratios. When the terminals were directly connected, figures obtained were better than those recommended by the C.C.I.F. With the terminals in conjunction with a 25-mile radio link, there was a 20 dB margin in the signal/noise ratio over the recommended value. This margin allowed for fading of the radio signal.

The choice of time division as a multiplexing method is

discussed, and the selection of the pulse repetition frequency, duration and time deviation is explained. A detailed description of the multiplexing equipment circuit is given, and both the performance specification and actual measured performance figures are tabulated. Finally the signal/noise ratio obtained with the radio link working over a 25-mile path is discussed, and the improvement which results from the use of pulse time modulation is explained.

An Experiment to test the Reciprocal Radio Transmission Conditions over an Ionospheric Path of 740 km

PAPER No. 1901 R; PART B

R. W. MEADOWS, B.Sc.(Eng.)

Two-way pulse transmissions made simultaneously on the same frequency (5·1 Mc/s approximately) between Slough and Inverness (740 km) are described. An aerial common to transmitter and receiver was used at each terminal, and the fading patterns displayed at each end were compared visually: the Inverness display was relayed to Slough over a Post Office trunk line for this purpose.

The fading of corresponding echoes was found to be non-reciprocal for about 1% of the time during a total period of observation of about 15 daylight hours spread over 13 days in May, 1954. The precautions taken to ensure that the effects were ionospheric and not instrumental are outlined in the paper.

Highland Water Power—The Developments of the North of Scotland Hydro-Electric Board

PAPER No. 1909 S; PART A

T. LAWRIE, C.B.E., M.A.

This paper, written a month or two before its author's sudden death, surveys the work of the North of Scotland Hydro-Electric Board. See also page 591. With hydro-electric schemes in the Highlands, amenity and the preservation of salmon fisheries are of great importance. Fish passes and hatcheries have been built, and waterfalls have been opened up.

There is one dam of pre-stressed concrete and the use of Trief cement in a large gravity dam is a promising development. The largest individual water turbine output is rated at 40 000 kW; the highest head of water employed is 1 362 ft.

For the year 1955–56, the average hydro-electric plant capacity will be about 634 000 kW and the annual output about 1 620 million kWh; the coal equivalent being about 960 000 tons, or over a fortnight's production of the Scottish coal pits. The output of 1955–56 is likely to be doubled in the ensuing ten years.

In 1948 half the total population of the supply area, including 93% of the farms and 99% of the crofts were without main electricity. A series of comprehensive distribution schemes is being carried out and half the farms and crofts and seven-eighths of the population are now connected to an electric supply.

SOME RECENT BOOKS

T. F. HUETER and R. H. BOLT

SONICS

NEW YORK: JOHN WILEY. LONDON: CHAPMAN AND HALL. 467 PP. £4.

The book has the sub-title "Techniques for the use of Sound and Ultrasound in Engineering and Science" and the word "Sonics" is defined in the text as "the technology of sound as applied to problems of measurement, control and processing." This definition describes more precisely the field covered by the book, the term sound being used to describe mechanical vibration, not confined to the audio range, in gases, liquids and solids. After an introductory chapter, discussing the scope of the subject and the M.K.S. system of units (which is used throughout), there follow two chapters on the basic principles governing mechanical wave-motion and radiation. The first of these chapters develops fundamental theorems and concepts in terms of two dimensions, whilst the second extends the results to wave motion in space. More specialized treatment is then given to piezo-electric and magnetostrictive transducers. Where possible, the action (and the relevant parameters) of the transducers, and the media in which they are acting, are expressed in terms of the equivalent electric circuit—a most useful means of facilitating a grasp of the subject by electrical engineers. Two chapters are then devoted to sonic processing, and they include discussions of sound fields in processing tanks, gas kinetics, particle agglomeration, cavitation in liquids and the selection and design of transducers for generating processing fields. The final chapter describes the principles of sonic testing and analysis. The book concludes with an Appendix with the general title "Acoustical Relaxation Mechanisms of Fluids," in which the influence of molecular properties on sound propagation is discussed.

It is the professed intention of the authors to provide sufficient fundamental material to give the reader (who is assumed to have had higher training "in any branch of science or engineering") an understanding of the physical principles involved, and also to include practical discussions with simplified engineering formulae and guidance for their use. The simultaneous accomplishment of these two broad aims is very difficult in any subject, especially when a very wide variety of scientists or engineers is being addressed. In preparing a textbook of reasonable length—in this case roughly four hundred and fifty pages—a dilemma must frequently arise as to how far one aim can be pursued at the expense of the other. Where there is insufficient space to treat fundamentals adequately the provision of simplified engineering formulae may be at best insufficient and at worst rather dangerous. This dilemma appears most evident in the chapter entitled "Physical Mechanisms for Sonic Processing," where much complex material is introduced and many formulae are given with a limited discussion which is not really satisfying. However, the authors have usually, and rightly, shown a rather greater bias towards fundamental

material and they have adopted the wise course of including full reference to representative original sources. The book is thus a valuable introduction to the subject in general, a good indicator to the techniques available and a source of reference to original, and more detailed, work for occasions where specialized and expensive design may be called for. The material is set forth in a pleasant and readable type and a very good standard of diagrams is maintained throughout. It can be recommended to those with a basic knowledge of electronics or communication engineering.

NOTES ET FORMULES DE L'INGENIEUR, VOL. IV (*revised by* M. DENIS-PAPIN and J. VALLOT)

PARIS: ALBIN MICHEL. 23RD EDITION. 2171 PP. £6.

The collection of notes and formulae for engineers, due originally to Laharpe, has run to 23 editions and now comprises four volumes. The present authors claim that the new edition is the most up-to-date and noteworthy technical reference work in the French language.

The volume under review is concerned entirely with electrical engineering and is divided into three parts: (i) Applied Electrotechnology (782 pp.); (ii) Telecommunication (406 pp.), and (iii) Electric Railway Traction (462 pp.).

The part dealing with applied electrotechnology is of general interest and covers the following subjects: transformers, rectifiers and convertors; batteries (primary and accumulators); testing of machines (a.c. and d.c.) and transformers; alternators for generating stations, switchgear (medium and low voltage) and protective gear; transmission lines (including electrical and mechanical calculations); low-voltage distribution networks and protective systems; voltage control; power-factor improvement; industrial motors (including applications to rolling mills, cranes and lifts); industrial electronics, including photocells, radiology, cathode-ray oscillographs and power rectifiers (mercury-arc, gas-filled, cuprous oxide and selenium, and contact); industrial furnaces (resistance, induction and dielectric); resistance and arc welding (including characteristics of electric arcs); illumination, lamps and lighting; industrial electrochemistry; electrometallurgy.

Under each subject the relevant theory is outlined and appropriate methods of calculation, together with requisite formulae, are shown. As an example of the way in which many of the separate sections form miniature textbooks, the section on transformers may be mentioned; the general theory of the transformer is given, and methods of calculating the dimensions of the core and windings, the best proportions of iron and copper, leakage reactance, losses and voltage regulation are all developed.

In contrast, the sections on protective systems and relays are somewhat disappointing; these subjects are dealt with scantily and the diagrams are meagre. For example, in the Merz–Price (misprinted "Herz–Price") circulating-current protection for transformers, a very poor diagram shows the application to a single-phase transformer, and no mention is made of the current-transformer ratios. Moreover, no applications of this system to 3-phase transformers are shown. The section on relays is confined principally to the telephone type and no information is given on induction-type relays.

Some of the diagrams are very poor and carelessly drawn, two very bad examples being the vee (or open-delta) connection of transformers (Fig. 393) and the waveform of the transient short-circuit current of an alternator (Fig. 601), the first two cycles of which are shown with wholly positive values and with descending half-waves whose slope changes sign (− to + to −) in passing from the maximum to the minimum values.

Notwithstanding these slight imperfections the first part of the volume contains many useful data and formulae for reference.

The telecommunication part includes the following subjects: line telegraphy (simple and multiplex systems, picture transmission, filters); electro-acoustics; line telephony (transmission-line theory, networks, line and cable construction; loading coils, repeaters, carrier-current and automatic systems); measurements; radio propagation (including waveguide theory); formulae for calculating inductance and self-capacitance of coils; oscillating circuits; aerials, arrays and feeders; electronics as applied to thermionic valves; parameters of diodes and triodes; amplification and amplifiers; transistors; multi-electrode receiving valves; ultra-high-frequency valves; radio-frequency measurements; transmitters; receivers; television (principles and systems); radar (general principles and theory); international allocation of radio frequencies.

The field of telecommunication is thus fairly well covered, except possibly submarine telegraphy and telephony, which are treated very briefly. Its value as a reference book is enhanced by the tabulated data of filters, attenuators, bridge circuits, etc., which show the conventional circuit diagrams and give the requisite formulae alongside. The tables of decibels and nepers, with the corresponding values of the ratios of powers and currents, are also valuable for quick reference.

The third part, dealing with electric railway traction, forms a useful reference work for the traction engineer, and provides him with up-to-date information concerning railway electrification in France, since the latest developments with single-phase 50 c/s current on the Valenciennes–Thionville line are incorporated.

The principal items considered in this part are as follows: data on railway electrification in France and other countries; mechanics of train movement; substations; catenary construction and contact systems (including mechanical calculations and impedance data); under-contact conductor rails; track circuits; reduction of interference between traction and telecommunication circuits; locomotives (types in service in France, bogie construction, running mechanics and stability); traction motors (electrical considerations, characteristics and speed control of d.c. and single-phase motors); locomotive control systems and auxiliary equipment; examples of d.c. and single-phase 50 c/s locomotives (direct, rectifier and convertor types); rheostatic and regenerative braking (d.c. and single-phase a.c.).

The reviewer's opinion is that the usefulness of the volume may be restricted by its high price. It is bulky (over 3 in thick), and one wonders if the concentration of two widely different and specialized subjects (telecommunication and electric railway traction) with a general subject (applied electrotechnology) provides the best combination for electrical engineers. The telecommunication and electric traction parts are each sufficiently extensive to form separate volumes, and the applied electrotechnology part, together with the more general electrotechnology section of Volume III could, with advantage, form another separate volume. The electrical engineer would then have the choice of handy and usable volumes, presumably at a reasonable price.

LOUIS N. RIDENOUR (*Editor*)
MODERN PHYSICS FOR THE ENGINEER

MCGRAW-HILL. 518 PP. £2 13s. 6D.

One of the most striking features of engineering during the past decade has been the great reduction in the time taken to harness new scientific discoveries to practical engineering applications. It follows that the present-day engineer can no longer afford to be ignorant of the most recent advances in physics, and while this is true of engineers in general it is particularly true of electrical engineers, whose subject is being revolutionized by the introduction of transistors and similar devices and by the use of nuclear energy. But, though the desirability of an up-to-date knowledge of physics is generally recognized, the time most engineers can devote to the subject is strictly limited. A need has therefore arisen for a concise presentation of the results of modern physics which, while omitting much of the detail required by the physicist, is nevertheless authoritative, does not seek to conceal difficulties and assumes a reasonable knowledge of mathematics on the part of the reader. The book under review represents one attempt to meet this need.

During the academic year 1952–53 a series of lectures was given in the University of California, Los Angeles, on a number of selected topics in physics, and these lectures have now been published under the editorship of Dr. Ridenour. Each set of lectures was given by an authority on the subject, and several physicists of international reputation contributed to the course. It goes without saying, therefore, that the lectures in book form provide a thoroughly sound résumé of those branches of physics with which the book deals. Moreover, the book is very readable and can be recommended with confidence to engineers seeking this kind of information.

A course of lectures given in this way suffers from difficulties of two kinds. In the first place, as Dr. Ridenour states in the preface, it was not possible to achieve much in the way of logical organization of the sequence of topics covered. Thus the book is not a textbook in the usual sense of the word, but a series of more or less unconnected chapters, which, for purposes of publication, have been grouped into three sections. The first of these, termed "The Laws of Nature," deals with familiar subjects such as Relativity, Atomic Structure, the Solid State, Magnetism, Microwave Spectroscopy and the more practical aspects of Nuclear Physics. All of these subjects are of great importance to the engineer and their inclusion is welcome. Similarly the last section, under the title "Information and its Communication," contains chapters on Electrons and Waves, Semiconductor Electronics, Information Theory and Computing Machines. Here again the electrical engineer will feel at home. In the second section the choice of subjects is more controversial. Under the heading "Man's Physical Environment" there are chapters dealing with Astrophysics, High-pressure Phenomena and Geophysics, The Earth Beneath the Sea, Thunderstorms and Transient Phenomena in Supersonic Flow. The connection of these subjects with engineering is less obvious, and electrical engineers will regret the omission of a chapter on the Ionosphere.

The second difficulty is inherent in the task the authors have undertaken and arises from the degree of condensation of subject matter which they have had to achieve. No one who has attempted this kind of exposition will wish to criticize their efforts and, indeed, most of them have succeeded admirably. The reader must realize, however, that he is being given only the bare outline of each topic and that for further information he must turn to the volumes listed at the end of each chapter. Used in this spirit, the book will provide most stimulating reading and can be wholeheartedly welcomed.

H. STÄGER (*Editor*)
WERKSTOFFKUNDE DER ELEKTROTECHNISCHEN ISOLIERSTOFFE

BERLIN: GEBRÜDER BORNTRAEGER. 2ND EDITION. 476 PP. £7.

The twenty-four years since the first edition of this work appeared have seen great advances in the field of insulation. Consequently the second edition has had to be a completely rewritten version, only the contributors and the form of presentation remaining almost unaltered.

The book surveys the present position in insulation technology, the contents being divided into three sections which cover gaseous, liquid and solid insulation. The two chapters on gases deal with their behaviour in electric fields, the process of breakdown, the formation of discharges and corona and the development of air-blast circuit-breakers. After a brief description of the use of water in circuit-breakers, the second section goes on to deal with mineral oils, chlorinated hydrocarbons, impregnants and casting resins. Of particular interest to engineers is the discussion of the chemistry of ageing and oxidation of oils under operating conditions, the catalytic action of metals used in electrical installations, the effect of the degree of refining and the action of inhibitors and stabilizing agents.

As might be expected from their variety and importance, the section on solid materials occupies the bulk of the book. It begins with an outline of crystal structure and solid-state physics which leads on to chapters on ceramics and inorganic glasses. The polymeric insulators are introduced by chapters which give excellent and comprehensive accounts of polymer chemistry, the relation of the mechanical and dielectric properties of a material to its structure (including the Debye theory of polar molecules) and a survey of the theories of dielectric breakdown. In the last chapter the author develops a phenomenological theory of "ionic breakdown." Under this theory, breakdown occurs when the voltage gradient, distorted by ionic space charges in the material, attains a critical value. This is applicable to materials which absorb ionic impurities such as moisture. The change of electric strength with thickness and temperature can also be accounted for, but the mechanism of breakdown is not considered in detail. The remaining chapters deal with the mechanical and electrical properties, behaviour and application of specific materials, namely paper, textiles and wood; rubbers; resins and varnishes; copolymers and polycondensates.

The practical value of the book is enhanced by the final chapter dealing with phenomena rather than with materials. The effect of such climatic conditions as humidity and temperature on the behaviour and life of insulation, and the occurrence of corrosion and tracking are receiving increased attention nowadays and are properly included.

The work steers a course between a handbook of properties and a textbook, giving a broad outline of the bases and problems of insulation technology. It should serve as a reference book for the practising engineer but is also a good starting-point for the intending specialist. Nearly every chapter has an extensive bibliography.

The book is well indexed and well produced, and with its many clear diagrams and tables is pleasant to read.

LIBRARY ACCESSIONS

**Denote that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members.*

BOOKS

TRUXAL, J. G. 621–52

Automatic Feedback Control System Synthesis

London, McGraw-Hill, 1955. pp. xiii, 675. 24 × 15 cm. £4 9s. 6d.

A review of the mathematical background, the basic theory of network synthesis and the applications of the Laplace transform and statistical design theory to linear systems. The book concludes with an introduction to the analysis and design of non-linear systems.

UDA, S., and MUSHIAKE, Y. 621.396.67

Yagi-Uda Antenna

Sendai, Japan, Tohoku University, 1954. pp. ix, 183. 22 × 15 cm. £2. *

Describes the results of the research work on this type of antenna which was developed by the authors, and explains the fundamental theories and gives practical design charts and data.

VINAL, G. W. 621.355

Storage Batteries

4th ed. New York, Wiley; London, Chapman and Hall, 1955. pp. xi, 446. 24 × 16 cm. £4

Describes developments in the industry since the third edition was published in 1940. They include improved lead alloys, new types of separators, and plastic containers for lead-acid batteries. Increased use of nickel–cadmium batteries is described and new types of silver-oxide cells. The book will be reviewed in a future issue.

WILLSMORE, A. W. 658.5

Modern Production Control

2nd ed. London, Pitman, 1955. pp. xiv, 185. 22 × 15 cm. 15s. *

Differentiates between jobbing shop production, batch production, and flow production, and explains the problems of planning associated with each. The survey covers the whole manufacturing process from the supply of the necessary materials, the breakdown of the work into stages, assembling the product, timing each operation, and the production of schedules.

WILLSMORE, A. W. 658.5

Product Development and Design

London, Pitman, 1950. pp. viii, 132. 22 × 14 cm. 12s. 6d. *

Discusses the factors contributing to the successful development of a saleable product—commercial considerations, technical research, protection of inventions, market research, product design, and production planning.

OTHER PUBLICATIONS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Proceedings of the Eastern Joint Computer Conference, Philadelphia, December 1954

New York, A.I.E.E., 1955. pp. 96. 28 × 22 cm. $3.

ASSOCIAZIONE ELETTROTECNICA ITALIANA

Rendiconti della 55th Riunione Annuale dell' A.E.I. Bellagio, 1954. Materiali. Fascicolo 1 and 2

Milan, A.E.I., 1955. pp. 40, 433. 30 × 21 cm.

BOARD OF TRADE. MONOPOLIES AND RESTRICTIVE PRACTICES COMMISSION

Collective Discrimination: A report on exclusive dealing, collective boycotts, aggregated rebates and other discriminatory trade practices

London, H.M.S.O., 1955. pp. iv, 111. 24 × 15 cm. 3s. 6d.

ÉLECTRICITÉ DE FRANCE

Fifth International Congress on Large Dams: Supplement to the review "Travaux" No. 247

Paris, Électricité de France, 1955. pp. 315. 31 × 24 cm.

NATIONAL ELECTRONICS CONFERENCE

Proceedings. Vol. 10. October 1954

Chicago, National Electronics Conference, Inc., 1955. pp. lxiv, 808. 23 × 16 cm. £2 2s.

NATIONAL PHYSICAL LABORATORY

Calibration of Temperature Measuring Instruments (Notes on Applied Science No. 12)

London, H.M.S.O., 1955. pp. iv, 47. 24 × 15 cm. 2s.

Noise Measurement Techniques (Notes on Applied Science No. 10)

London, H.M.S.O., 1955. pp. iv, 40. 24 × 15 cm. 2s.

Precision Electrical Measurements. Proceedings of a Symposium held at the National Physical Laboratory, November 1954

London, H.M.S.O., 1955. pp. xxii, 351. 26 × 20 cm. £1 7s. 6d.

ORGANISATION FOR EUROPEAN ECONOMIC COOPERATION

Technical Information. Report on the first meeting of technical information officers held at the D.S.I.R. from 27th September to 1st October, 1954

Paris, O.E.E.C., 1955. pp. 68. 24 × 15 cm. 2s.

PHYSICAL SOCIETY

Report of the Physical Society Conference on the Physics of the Ionosphere held at Cambridge, September 1954

London, Physical Society, 1955. pp. 450. 26 × 18 cm. £2.

RADIO-ELECTRONICS-TELEVISION MANUFACTURERS ASSOCIATION

Report of the Conference on Reliability of Electrical Connections, April 15th–16th, 1954

New York, R.E.T.M.A. pp. 76. 27 × 21 cm. 1954. $5.

ROSSITER, G. E.

Coaxial Cables—Some Practical Aspects of their Design and Maintenance

London, Institution of Post Office Electrical Engineers, Paper No. 205, 1953. pp. 17. 28 × 22 cm. 2s. 8d.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH AUGUST, 1955

	No. of Contributors	£	s.	d.
£1 000 and over	6	6000	0	0
£100 to <£1 000	29	6386	3	0
£5 to <£100	770	8375	14	5
£2 to <£5	1822	5027	8	8
Under £2	17610	9355	0	9
		£35144	6	10

PROGRAMME OF MEETINGS: 1955–56 SESSION

The programme card of London meetings for the first half of the session is being sent with this issue to all members living in the following counties:

Bedfordshire
Berkshire
Buckinghamshire
Essex (less that part coming within the area of the East Anglian Sub-Centre)
Hertfordshire
Kent
Middlesex
Oxfordshire (less that part coming within the area of the South Midland Centre)
Surrey
Sussex (less that part coming within the area of the Southern Centre)

Members living outside this area will receive, in due course, the programme cards of the Local Centres to which they are attached.

Any member living in the provinces who often visits London and is thus able to attend London meetings may obtain a copy of the London programme card on application to the Secretary.

MEMBERS' GUESTS

Members are reminded that, under the Bye-laws of The Institution, every member (Students excepted) is entitled to introduce one visitor at each Ordinary Meeting. By direction of the Council, this also applies to all meetings of the Measurement and Control, Radio and Telecommunication, Supply, and Utilization Sections, and to the Informal Meetings.

DISCUSSIONS AT MEETINGS

The Council desire it to be understood that contributions to the discussions at meetings should not be read from manuscript, since they consider that this form of presentation is contrary to the true spirit of a discussion.

WRITTEN CONTRIBUTIONS TO DISCUSSIONS

Members who are unable to be present at a meeting, or who, if present, do not have an opportunity of speaking, may submit written contributions to the discussion which will be considered for publication in the *Proceedings*. This does not apply to Informal Meetings or Discussion Meetings.

We would also remind members that written contributions on papers published in the *Proceedings* without being read at meetings will be considered for publication.

Members should note that the Papers Committee have been obliged to set a limit of 500 words for contributions of either sort.

BRITISH NUCLEAR ENERGY CONFERENCE

INAUGURAL MEETING

The first meeting of the Conference will take the form of a Lecture Symposium and will be held at The Institution of Civil Engineers from 2.15 p.m. to 8.15 p.m. on the 30th November, 1955.

The meeting will be opened by the Chairman of the Conference, Sir Christopher Hinton, M.A., M.I.Mech.E., F.R.S., after which the following lectures will be delivered:

The United Kingdom Atomic Energy Project, by Sir John Cockcroft, K.C.B., C.B.E., M.A., M.Sc.Tech., Ph.D., F.R.S., M.I.E.E.

The Place of Nuclear Energy in United Kingdom Power Development, by V. A. Pask, C.B.E., M.I.Mech.E., M.I.E.E., and J. A. Duckworth, B.A.

The Use of Research Reactors in Nuclear Power Development, by H. J. Grout, B.Sc., A.M.I.Mech.E.

Health and Safety in a Nuclear Power Industry, by A. S. McLean, M.B., Ch.B., D.I.H., and W. H. Marley, M.Sc., Ph.D.

There will be an interval for tea from 4.45 p.m. to 5.15 p.m. after the paper by Mr. Pask and Mr. Duckworth.

Owing to limited accommodation, attendance at the Symposium will be confined to members of the five constituent Societies, and members of The Institution who wish to attend are requested to apply as soon as possible to the Secretary of The Institution for a ticket of admission.

The first issue of the B.N.E.C.'s journal containing the lectures, will be published in January, 1956, and the annual subscription rates are as follows:

Members of constituent bodies	30s., post free
Non-members	60s., post free

An order form for the B.N.E.C.'s journal will be included with the October issue of the *Journal of The Institution.*

CONVENTION ON AIRCRAFT ELECTRICAL EQUIPMENT

MAY, 1956

The Convention on "Electrical Equipment of Aircraft," announced in the April *Journal* will be held from the 2nd to 4th May, 1956, and the provisional programme is as follows:

Wednesday, 2nd May, 1956
Evening: Opening Session.
Thursday, 3rd May, 1956
Morning: Session 2. Electricity in Aircraft.
Afternoon: Session 3. Aircraft Electrical Systems.
Evening: Session 4. Installation and Maintenance.
Friday, 4th May, 1956
Morning: Session 5. Machine Equipment.
Afternoon: Session 6. System Equipment.

Further details will be announced in due course.

NOMINATIONS

BRITISH STANDARDS INSTITUTION TECHNICAL COMMITTEES:

Sub-Committee on Refrigeration Thermometers on Ships (INE/4/5)

The Council have nominated Mr. W. Bamford, B.Sc.(Eng.), Member, to serve as their representative on the above Sub-Committee.

Hydraulic Turbines (*MEE/125*)
The Council have nominated Mr. P. L. Blackstone, T.D., M.A., Member, to serve as their representative on the above Committee in place of Mr. J. E. Calverley, Member.

PUBLICATIONS OF THE INSTITUTE OF PHYSICS

Members are advised that from the 1st January, 1956, the charge to them for the *Journal of Scientific Instruments* published by the Institute of Physics will be £2 10s. instead of £2 per year as at present. The charge for the *British Journal of Applied Physics*, also published by the Institute of Physics, remains at £2. It should be noted that these privilege rates apply to only one of the publications for each member; a combined subscription to the two publications for a member is now £6 10s.

CONFERENCE ON ELECTRICAL INSULATION

The Annual Meeting of the American Conference on Electrical Insulation (under the auspices of the National Academy of Science's National Research Council) will be held at Pocono Manor, Pennsylvania, from the 17th to 19th October, 1955. The topics of the technical sessions of the Meeting will be determined by the papers submitted. A new feature at the Meeting will be the first J. B. Whitehead Memorial Lecture; the name of the lecturer will be announced later. Ladies will be welcome at the Meeting, and social events are being planned. Members who desire to submit a paper for reading should write immediately to the Chairman of the Programme Committee, Dr. Harry A. Sharbaugh, at the Research Laboratory, General Electric Company, P.O. Box 1088, Schenectady, New York, sending a brief abstract of the proposed paper. Further particulars of the Conference may also be obtained from him.

THE HUMAN PROBLEMS OF INDUSTRY

H.R.H. THE DUKE OF EDINBURGH'S CONFERENCE

In Oxford from the 9th to 27th July, 1956, there will be held an industrial Conference with wide terms of reference. Its aim will be to study the human aspects of industrialization—in particular the causes of satisfaction, efficiency and understanding in both the internal and external relations of industry; it will not however consider matters covered by normal industrial negotiation. The Conference, whose outline programme is now available, is known as "H.R.H. The Duke of Edinburgh's Study Conference on the Human Problems of Industrial Communities within the Commonwealth and Empire." His Royal Highness, an Honorary Member of The Institution, has, as President of the Conference, written a Foreword, which closes with the words:

> I cannot emphasize too strongly that this is a study conference not for research workers but for young people actually engaged in industry . . . Its value will depend upon what the members make of what they see and hear . . . It is hoped that the members will be able to extend their influence in their own countries and industries to the end that industrial enterprises are so organized that they form an integral part of a happy and healthy community.

All proposals for membership of the Conference (limited to 90 members from the United Kingdom, 135 from other countries of the Commonwealth and 55 from the Colonial territories) must be made through an industrial undertaking, trade union, nationalized enterprise or other appropriate body. Broadly, those taking part will be aged between 25 and 45 and will be persons engaged in managerial, technical or operative activities who hold responsible positions.

Enquiries should be addressed to the Conference Secretary, Administration Headquarters, 48 Bryanston Square, London, W.1.

WORLD POWER CONFERENCE

The British National Committee have now announced the titles and authors of 26 papers for presentation at the Fifth World Power Conference, which is to take place at Vienna in June, 1956. (See March *Journal*, page 201.) Fixtures arranged for later dates include Sectional Meetings in Yugoslavia (June, 1957), Montreal (September, 1958) and Switzerland (1960), and the Sixth (Plenary) World Power Conference in Australia in 1962.

At the recent Annual General Meeting of the British National Committee Sir John Hacking, Past-President, was re-elected Vice-Chairman.

THIRTEENTH EDITION OF THE WIRING REGULATIONS

The Thirteenth Edition of "Regulations for the Electrical Equipment of Buildings" has now been published by The Institution, and supersedes, as from 1st September, 1955, the Twelfth Edition. Some information about its preparation, its presentation in two distinct parts and its contents was given in the July *Journal*, page 403. In the Thirteenth Edition the Regulations have been reviewed as a whole; as a result many of them have been rearranged and reworded.

The present edition takes into account comments received since 1950 and proved advances in installation techniques.

The Temporary Relaxation, 1952, dealing with the ratings of certain cables, and the Abridged Wiring Regulations, issued for the first time on the 15th November, 1951, are now withdrawn. No decision will be made about the preparation of a revised abridged version until it becomes clear whether the greater conciseness of the Thirteenth Edition has removed the need for one.

The Recommended Practice for Caravan Installations, first issued on the 1st February, 1954, although prepared during the currency of the Twelfth Edition of the Wiring Regulations, is self-contained, and will continue to be available.

Copies of the Wiring Regulations may be obtained from the Secretary, at the following prices: paper, 6s. (post free); cloth boards, 8s. 6d. (post free).

STUDENTS' QUARTERLY JOURNAL

The contents of the September issue of the *Students' Quarterly Journal* are as follows:

"Inventions and Their Influence on Industrial Organization and Management," by W. G. Bryce, B.Sc.
"Gas Turbines for Electrical Power Generation," by E. H. Nicholson, M.A.
"Ground Resonance Testing of Aircraft," by A. H. Dick, B.Sc.
"London Section Summer Outing," by K. W. E. Gravett, M.Sc.(Eng.).
"Radio Aids to Marine Navigation," by William Tulloch.
"Potted Circuits and Printed Wiring," by R. Fairfax Naylor.
"A Vector Calculator," by J. S. Edmondston, B.Sc.(Eng.).
"The Art of Interior Lighting," by R. A. Grace.
"Stereophonic Sound Reproduction," by G. C. Richards.
"Electronic Control of Resistance Welding," by Z. Heczko, B.Sc.(Eng.).
"The Development of Telephone Exchange Systems," by T. M. Dowell, B.Sc.

SPECIAL COURSES IN HIGHER TECHNOLOGY

A programme of specialized courses to be held at technical colleges in London and the Home Counties, during the Autumn term, 1955, has been issued by the London and Home Counties Regional Advisory Council. The bulk of these courses are part-time, mostly evening classes, but a few full-time courses of not more than three months' duration are included. The courses cover a very wide range of specialized aspects of electrical and mechanical engineering, mathematics, physics, chemistry, metallurgy, management, accountancy, industrial law, engineering economics, organization, statistics, etc.

Most of the courses begin in October, except for a few whose starting date is September. Details of a particular course and the date of registration may be obtained from the college in question. The fees for these advanced courses are approximately one guinea for six lectures, up to a maximum of four guineas, although prospective students should ascertain the fees payable at a particular college.

Those interested in the courses will find further details in the "Bulletin of Special Courses in Higher Technology," issued by the Secretary, Regional Advisory Council, Tavistock House South, Tavistock Square, London, W.C.1, price 1s. 6d., post free.

SYMPOSIUM ON MAGNETIC MATERIALS

The Electronics Group of the Institute of Physics will be holding a symposium on "Some Recent Developments in Magnetic Materials" in the Institute's House on the 23rd and 24th September, 1955. Seven papers will be read and discussed. Further details may be obtained from the Deputy Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

INDUSTRIAL STUDIES AT BIRMINGHAM UNIVERSITY

EXECUTIVE COURSES

The Institute for Engineering Production has announced a series of short, practical, residential courses for executives on the principles and methods of increasing productivity. The various courses, which last a fortnight each and are limited to a membership of 25, are on the following subjects:

Work Study, including methods improvement, work measurement and incentives.

Production Planning and Control, including the analysis and improvement of procedure and organization.

Operational Research, dealing with the improvement of operating policy through the quantitative analysis of all factors affecting operating efficiency.

The first course will start on September 12th, and the others will follow consecutively. They will be held at "Southfield," a magnificent institute acquired by the University in 1953. The inclusive fee for each course, covering textbooks, course papers and all residential charges and meals, is £40 per member. Where members are unable to attend as residents, the fee will be £30. Details may be obtained from the Senior Courses Secretary, The Institute for Engineering Production, "Southfield," 16 Norfolk Road, Edgbaston, Birmingham 15.

INDUSTRIAL ADMINISTRATION

A six-week full-time course entitled "The Practice of Work Study" will be offered by the Birmingham College of Technology for three separate periods, beginning on the 19th September, 1955, in January, 1956, and in April, 1956.

A second six-week full-time course entitled "Organization and Control of Production" will begin on the 7th November, 1955, and again in February, 1956.

The fee for each of the above courses is 50 guineas, and details may be obtained from the Birmingham College of Technology, University of Birmingham, Edgbaston, Birmingham 15.

SYMPOSIUM ON MICROWAVE TECHNIQUES

A symposium on microwave techniques will be held at the University of Pennsylvania, Philadelphia, on the 2nd and 3rd February, 1956, sponsored by the Institute of Radio Engineers. The sessions will include the following topics:

Radiating Systems, including radomes, techniques of antenna gain and pattern measurement, the use of near-field measurements, and problems associated with paraboloid antennas of over 20 ft diameter.

Guided Microwave Transmission, including rectangular guides, ridge guides, round guides, dielectric guides, and single-wire guides.

Components, including filters, convertors, duplexers, directional couplers, and non-reciprocal components.

Propagation, including scatter.

Measurements, including power, spurious emission, spurious modulation, emission bandwidth, and gain standards.

Full details of the symposium may be obtained from Mr. D. R. Crosby, Radio Corporation of America, Building 10-1, Camden 2, New Jersey, U.S.A. Summaries of papers to be submitted must reach Mr. Crosby not later than the 15th October, 1955.

ELECTRO-HEATING CONFERENCE

A conference will be held at Essen on the 9th and 10th November, 1955, to discuss problems concerning industrial process heating. The programme for the first day has been prepared by the Vereinigung Deutscher Elektrizitätswerke and will cover: (i) electro-heating and electricity supply; and (ii) interference of arc furnaces with electrical networks.

The programme for the second day has been prepared by the Verband Deutscher Elektrotechniker, the Elektrowärme-Institut Essen-Langenberg and the Arbeitsgemeinschaft Deutscher Betriebsingenieure im Verein Deutscher Ingenieure, and deals with the applications of electro-heating in the metallurgical industry.

Members who are interested in this meeting should write to Dr. Lauster, Verband Deutscher Elektrotechniker e.V., Osthafenplatz 6, Frankfurt am Main, who will be pleased to send them a complete programme at the end of September.

A CORRECTION

JOURNAL, JANUARY 1955

On page 11 of the January *Journal*, left column, the lower displayed formula should read

$$\text{“}x_0 = 100V'/V = 1{\cdot}6aN^2P/V^2\text{”}$$

instead of

$$\text{“}x_0 = 100V'/V = 0{\cdot}16aN^2P/V\text{”}$$

THE JOURNAL REFERENCE SECTION *(pages 615-620)*

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North Midland Centre
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•G. CATON

North-Eastern Centre
G. W. B. MITCHELL, B.A.
•H. ESTHER, B.ENG.

North-Western Centre
PROFESSOR E. BRADSHAW, M.B.E., M.SC.TECH., PH.D.
•H. WEST

Northern Ireland Centre
MAJOR P. L. BARKER, B.SC.
•J. R. W. MURLAND, B.SC.(ENG.)

Scottish Centre
J. S. HASTIE, B.SC.(ENG.)
•C. H. A. COLLYNS

South Midland Centre
A. R. BLANDFORD
•H. J. GIBSON, B.SC.

Southern Centre
E. A. LOGAN M.SC.
•CMDR. C. V. ROBINSON, R.N., O.B.E.

Western Centre
A. N. IRENS
•J. VAUGHAN HARRIES

• *Past-Chairman.*

SECRETARY W. K. BRASHER, C.B.E., M.A., M.I.E.E.

Deputy Secretary F. JERVIS SMITH, M.I.E.E.

Assistant Secretary F. C. HARRIS

Editor-in-Chief G. E. WILLIAMS, B.SC.(ENG.), M.I.E.E.

***Journal* Editor** C. T. RIVINGTON, M.A., A.M.I.E.E.

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 1st June, 1955.

ELECTIONS

Associate Members

BARBOUR, John.
GRAY, Agnes Gibb (Miss), M.B.E., M.A., B.Sc., LL.B.
KNOX, James Main, B.Sc.
LAWSON-BROWN, Maurice Crompton.
McGOWAN, Norman Leslie, B.E.
MOSS, Samuel Hyam, B.Sc., B.A.
PERRY, Ernest Thomas.
RICHARDS, Frank Alfred.
SANDERSON, John Laurence.
SINGH, Gulab, B.Sc.
STEWART, Innes Ogilvie.
SUTTON, Richard Thomas.
TILLMAN, John Richard, D.Sc., Ph.D.

Companion

RAINE, Philip Alexander.

Associates

BETTERIDGE, Philip.
DOUGHTY, Henry John.
FLEMING, Andrew.
NEALE, George Matthews, Lt.-Cdr. R.A.N.
PATERSON, Robert John Easton.
PAVELY, Philip Sidney.
PHILLIPS, Graham.
POOLE, William Nolan, B.Sc.
TURICK, Paul Alexander.

TRANSFERS

Associate Member to Member

ABERCROMBIE, David John, B.Sc., B.E.
BENHAM, Cedric Minett, B.Sc.(Eng.).
BOWYER, Eric, B.Sc.Tech.
BOZZOLI, Guerino Renzo, D.Sc. (Eng.).
ELDRED, Eustace Macdonald.
ERROLL, Frederick James, M.A., M.P.
FABER, Oscar, C.B.E., D.Sc.
GILLAM, Gerald Hugh.
HUGHES, Leslie Ernest Charles, B.Sc.(Eng.), Ph.D.
MENZIES, Andrew.
NICHOLSON, John Duncan, B.Sc.
RADWAY, Ernest Raymond.
REWCASTLE, William, B.Sc.
RICHARDS, John Howard, M.A., B.Sc.
SMITH, Ian Stewart, B.Sc.
VARMA, Hans Raj.

Associate to Associate Member

GODDARD, Captain John, B.A.
MAGOWAN, John McKee.
POWER, Jack Milgrew, B.Sc.

Graduate to Associate Member

AIYAR, Srinivas Subramania.
ALLSOP, John Alfred.
ARTHUR, Raymond David.
AUSTIN, Edward Ralph, B.Sc.(Eng.).
BEALE, Anthony Peter, B.Sc.(Eng.).
BLISS, Leonard William.
BRATTON, Ernest, B.Sc.(Eng.).
BROWN, Angus Ross.
BROWN, Joseph Anthony.
BROWN, Reginald David.
BRYSON, Lindsay Sutherland, Lt. R.N., B.Sc.(Eng.).
BUDEIRI, Najib Aref, B.A., B.Sc.
BYRNE, Thomas.
CHAPMAN, Peter William Palmer, B.E.
CLEMENTS, Donald Fraser.
COPE, Philip George.
DAVIES, John Harold, B.E., B.Sc.
DAWE, Leonard Stanley, B.Eng.
DENTON, Paul Mowbray.
DURIGAN, Frank Wilkinson, B.Sc. Tech.
EDMUNDS, Kenneth Edmund.
EDWARDS, Keith.
FIELDING, Geoffrey.
FORSTER, Jim, B.Sc.Tech.
HALLS, Richard Walter.
HARDY, Francis Edward Meredith, B.Sc.(Eng.).
HENDERSON, Henry Horsley Mason.
HILL, John Cureton.
HIRD, Eric Ellis, B.Sc.(Eng.).
HOLLIDAY, Sydney.
HOWELL, Ronald Thomas Albert, B.Sc.(Eng.), Ph.D.
JONES, Peter Batham, B.Sc.(Eng.).
LAVENDER, Kenneth George, B.Sc. (Eng.).
LEWIS, William Edwin, B.Sc., Ph.D.
MARLAND, John.
MOCKLER, Patrick John, B.Sc. (Eng.).
MORGAN, Eric John.
MYERS, Michael.
NEEDHAM, Charles Francis.
NEWMAN, Richard Arthur Arno, B.Sc.(Eng.).
NEWSON, Peter Anthony, B.Sc.
NICHOLLS, Lionel Gordon Talbot.
NICHOLSON, Ernest Harvey, M.A.
PARRY, John Vaughan, M.Eng.
PRATT, Frederick Carey, B.Sc.
PRICHARD, Gordon Frank, B.Sc. (Eng.).
RAFTERY, Bernard William.
SHACKLETON, Kenneth William.
SHAW, Geoffrey Louis.
SNELL, John David, B.E.
SRIVASTAVA, Tirjugi Nath, M.Sc.
TEMPLETON, John, B.Sc.
THOMSON, Robert Peel, B.E.
WORRELL, Alan Francis, B.Sc.Tech.

Student to Associate Member

DALE, Percy William George.
DICKIE, John.
HOPKINS, Ronald Sydney, B.Sc. (Eng.).
KINSMAN, William Audley.
MELLOR, John Thompson.
MORGAN, George Robert, B.Sc. (Eng.).

The following elections and transfers approved by the Council are effective from the 23rd June, 1955.

ELECTIONS

Graduates

BARTER, Geoffrey Frederick George.
BASU, Sudhir Kumar, B.Sc.
BATTAREL, Claude Pierre, Ing.E.S.E. (Paris).
BESHAW, Eric George.
BURGESS, Alan Mitchell, B.A.
CHOWN, John Bertram Norman.
CORNISH, Ezra Ernest Charles.
COXE, Peter Cockle.
CRANK, Geoffrey James, B.Sc.(Eng.).
DALAKER, Kjell Inge, B.Sc.
DAVIES, David Arthur, B.Sc.(Eng.).
EVERETT, Raymond Martin, B.Sc. (Eng.).
FANTHOME, Bernard Alan, B.Sc. (Eng.).
GALBRAITH, John Russell, B.E.
GORMLEY, Lawrence Brendon, B.Sc.
HOLMES, John Charles, B.Sc.
HULBERT, Laurence Roy.
JONES, Frederick David.
JOWIEC, Pankracy George.
KNIGHT, Douglas Frank.
LACHS, Walter Ralph, B.E.
MITRE, Ajit.
MUKERJI, Mohi Mohon, M.Sc.
MURRAY, Patrick Leigh.
NEWTON, Frank Allan, B.Sc.
OLCZAK, Henryk.
OPIE, Stephen Rex Browning, B.E.E.
ORBACH, Antony Zygmunt.
PRICE, Alfred.
ROSS, Gilbert Hamilton.
SHARMA, Parash Ram, B.Sc.
SHERRATT, Frank Brian, B.Sc.(Eng.).
STOKER, Maurice Frederick.
THOMAS, Walter Adekanmbi Ladipo.

Students

AHMED, Samir Abdel Aziz.
ANTIPPA, Jerassimo.
BENNETT, Peter John.
BIRCH, Robert.
BOOTY, Raymond Charles.
BRADBURY, Ian John.
BROOKS, Donald Peter.
BUNYAN, Michael John.
CARMICHAEL, Ian Francis.
CARRINGTON, Leslie.
CHONG, Erik Kwok Hoong.
CHU, Albert Chien Dean.
CLARK, John Stewart.
CLEARY, Kevin Patrick.
CLEMENTS, Robert Augustus, M.Sc.
COOPER, Norman, B.Sc.
CROWE, John Phelps.
CYSTER, William John.
DAKIN, Christopher John.
DAVIES, William Moelwyn.
EARLY, Alexander.
EDLINGTON, Malcolm John Brian.
ELLEM, Neville James.
GEMMELL, Michael John.
GILBERTSON, Geoffrey Roger.
GOLDHAMMER, Arthur Brian.
GRAHAM, Donald.
GRIEVE, Bruce Leslie.
GRIFFITHS, Ronald.
HARRIS, David Crerar.
HAWLEY, Robert.
HEATHERLEY, Joseph Charles.
HIRA, Indu Dharamdas, B.E.
HOLME, Reginald Alfred.
HUMBY, John Edwin.
HUTT, Bryan John.
JAMES, Allan.
JONES, Tudor Morris.
LAY, Peter John.
LEAMING, Donald Sydney.
LEE, Royston George.
McINTOSH, Ranald.
MAINO, Raymond John.
MATTHEWS, John Jenkin.
MELBOURNE, Alan Johnson, Flying Officer R.A.F., B.Sc.
MORGAN, Henry.
MURGATROYD, Melvyn.
PARKER, John Martin.
PATEL, Nanubhai Chhotubhai.
POLLARD, John Desmond, B.A., B.A.I.
PRIMLANI, Ram.
PURANIK, Hari Keshav, B.Sc.
RAJA RAO, Yadatore Narayanarao.
RIVO, Lars Kristen.
ROCKY, Michael Stanley.
SAUNDERS, Michael William.
SMITH, Ivan Ronald.
STREET, Brian Dudley Frederick.
TALUKDER, Banajit Kumar, M.Sc.
TINTO, Kenneth Desmond Francis.
TOWNSEND, Derek.
TREUREN, Gustaaf Hendrik George.
TURNBULL, Thomas James.
TWEEDLEY, William George.
VELSAMY, Appathurai.
VENKATANARAYANAN, Ramachandra, B.E.
VINES, John Murray.
WABY, George Thomas.
WARING, Harry.
WATKINS, Frank Edward.
WELCH, Donald Henderson.
WHEELDON, William Edward.
WILLIAMS, Brian George.
WINFIELD, John Roger.
WONG, Donald.
WOODFORD, Brian Vincent.
WOODLEY, David James Allan.
WYKES, Lewis Dellow.
YOUNG, Kenneth Beresford.

TRANSFERS

Student to Graduate

ASHENDEN, Derek Bryan.
BALL, Arnold George, B.Sc.(Eng.).
BENNETT, Brian Donald, B.Sc.(Eng.).
BROWN, Rodney Thomas, B.Sc. (Eng.).
CHARLES, Michael David, B.Sc.
CILIV, Hamit, B.Sc.
DADD, Ronald Harry, B.Sc.(Eng.).
DEAN, Arthur Kenneth.
ELGAR, John Edwin.
FARRELL, Malcolm Reginald.
FIANDER, David Charles, B.Sc. (Eng.).
FORDYCE, Malcolm Stanbury.
FORREST, John Alan Clarkson.
GRANSDEN, Derek Robert Davison, B.Sc.
HALIM, Hasan, B.Sc.
HAZRA, Karunamoy, B.Sc.(Eng.).
HOLMES, Frederick Arthur.
HOLROYD, John Brian, Sub.-Lt. R.N., B.Sc.
HOOPER, Daryl Egbert, B.E.E.
HOPES, Peter John.
KAYE, Alan Stanley.
MIOTLA, Jan.

Student to Graduate (contd.)

RORKE, Daniel McColl, B.Sc.(Eng.).
SARKAR, Ajit Kumar, B.Sc.
SHAH, Jayantilal Kapurchand, B.Sc., B.Sc.(Eng.).
SIMMONS, John David Carilon,
STEPHENSON, Ian Meredith, M.Sc. (Eng.).
SWEETT, Leonard John.
TOMLIN, Roy Donald.
WALLER, Patrick Neil.
WOOD, David, B.Sc.(Eng.).

The following elections and transfers were approved by the Council during July and August, 1955.

ELECTIONS

Member

LAWTON, Frederic Lewis, B.A.Sc.

Associate Members

ARCHER, Alva Izak, M.Sc.(Eng.).
BARKER, John.
BEAL, Richard Ernest, B.Sc.
BENNETT, John Makepeace, B.E., B.Sc., Ph.D.
BEYNON, William John Granville, Ph.D., D.Sc.
BOGGIS, Arthur George, Sqdn.-Ldr. R.A.F.
BUCKLEY, Harry Arnold.
CLEGG, Jeffery Ashwick, M.Sc.(Eng.).
CORCORAN, Noel, B.A., B.Sc., M.Sc. Tech.
DIX, Cyril Henry, B.Sc.
GAC, Adam Wincenty.
GRIMBLEY, John.
HEATH, George Albert, B.Sc.(Eng.).
HOWARD, John Arthur, Lt. R.N., M.A.
JENNINGS, Henry Walton, Lt.-Cmdr., R.N., B.Sc.(Eng.).
KEIGHLEY, Norman.
KING, James Charles Bishop.
LAWSON, Henry.
LEDGER, Basil Edward, B.Sc.
METCALFE, Albert Alan.
MITCHEM, Eric Ralph.
MURRELL, Alfred Capper.
OGDEN, Harold.
PIGRAM, Albert William.
PRATT, Roger Francis, Lt.-Col. R.E., B.A.
SAKUNWADHNA, Chalerm, Lt.-Cmdr., R.T.N., B.Sc.
SETH, Ian Peter.
SOMMERSCHIELD, John Graham.
SWALLOW, John William.
TOWNSEND, George Boris, B.Sc.
VASNAIK, Michael Albert Joseph, B.Sc.(Eng.).
WORTHY, William Digby, M.A.

Associates

BATT, Thomas David.
BRADY, Albert Francis.
DASGUPTA, Sailesh Chandra.
FIELDEN, Cyril Fred Raymond.
HAMILTON-SCHASCHKE, Douglas.
HANNAFORD, Fred.
HITCHCOCK, George Glenning.
KUMAR, Rajendra Nath, Lt.-Col., R.N., B.A.
LACEY, Sydney Hubert.
LEUTY, Stanley.
LITTLEWOOD, George Reginald.
McGILL, John Donald.
ROWBERRY, Edward John.
ROWLANDSON, Arthur Hadden, Cmdr. R.N.
SMEDLEY, Leonard.
STONER, Ernest George.
TAYLOR, James Francis.
WHITEHEAD, Edward Ashworth.

TRANSFERS: 1ST LIST

Associate Member to Member

ALLEN, Robert.
ARMSTRONG, Reginald Basil, B.Sc.
COOKSON, John Francis, B.Sc.
COPLAND, Frederick George, B.Eng.
DAGLISH, Peter John, B.Sc.
DONNELLY, Patrick Joseph.
FENEMORE, Alan Stephen, B.Sc. (Eng.).
HAWKESLEY, Edgar.
KYNOCH, Frederick Sinclair.
LAWSON, Charles John Vivian.
LINAY, Edward Curzon.
LONG, Arthur Leslie, B.Sc.(Eng.).
LOWE, Vernon Warwick, B.Eng.
OLDFIELD, Norman, B.Sc.(Eng.).
PARSONS, William Richard, B.Sc. (Eng.).
ROLFE, Norman Charles, B.Sc.(Eng.).
SLOANE, Professor Robert Wood, M.A., Ph.D., B.Sc.
TOWERS, Richard Walter.

Associate to Associate Member

HUTCHINSON, John Stevens.

Graduate to Associate Member

ABBOTT, Anthony Roger.
ADIE, George, B.Sc.
AIMER, Hugh Kenneth, B.E.
ALLEN, William Walsh.
BAILEY, Reginald George.
BALDWIN, Roy.
BAMBER, Francis William.
BARKER, Hedley Keith, B.Sc.
BERKELEY, Philip Roland.
BERNON, Bernard Aubrey.
BLEACH, John Westcott, B.Sc.(Eng.).
CAMPBELL, Douglas Hamilton.
CLARKE, Clifford, B.Sc.
CLOTWORTHY, Neil Desmond.
COGLIN, Stanley Robert.
COMRIE, Alexander Peter, Lt. R.N.
COOPER, William Thomas Donald.
CORPS, Reginald John, B.Sc.
COWIE, Alexander Grant.
CUMMINGS, Donald Harry, B.Sc. (Eng.).
DE MATTOS, David Neville, B.Sc. (Eng.).
DOVE, Frank, B.Sc.
EDWARDS, Gerald James, B.Sc. (Eng.).

Graduate to Associate Member (contd.)

ELLIOTT, Peter Leonard.
FLOSSMAN, Kurt Richard, B.Sc.
GAINES-BURRILL, Alwin, B.Sc. (Eng.).
GHOSH, Bankim Behari, M.Sc.
GIBBS, Francis John, B.Sc.(Eng.).
GORDON, Robert Louis, B.Sc., Ph.D.
GRANGER, Alan Tilney, B.Sc.
GRIFFITHS, William Edward.
HAMBY, Douglas Roy.
HARPER, Ronald Francis.
HARRIS, Philip Arthur Lester, B.Sc. (Eng.).
HARRISON, Ronald Edward, B.Sc. (Eng.).
HARVEY, Thomas, B.Sc.(Eng.).
HAWKES, John Sydney, B.Sc.(Eng.).
HORE, Richard Anthony, M.A., B.Sc.
ILYAS, Syed Mohammed, B.Sc., M.Sc.(Eng.).
JONES, Glyndwr James, B.Sc.
KEEN, Geoffrey Howard, B.Sc.
KENNEDY, Donald Alexander.
KING, Alan Victor.
LAWLER, James Alan.
LLEWELLYN, Norman.
LOCKWOOD, Harold Douglas, B.Sc. (Eng.).
MARR, Grigor Wilson, B.Sc.(Eng.).
MOLE, Cecil John.
MORTON, William Desmond, B.Sc.
NEWBERY, Kenneth Charles, B.Sc. (Eng.).
ORDE, Frederick Kenzo.
RICHARDS, John, B.Sc.(Eng.).
ROUT, Eric Raymond.
RUFFHEAD, Philip Geoffrey.
RUSHTON, James.
RUSSELL, William Thomas, Lt.
SEDDON, Frank, M.Eng., B.Sc.(Eng.).
SHARP, Keith Cranley.
SKELTON, George Henry.
SMILLIE, James, B.Sc.(Eng.).
SOPER, John Alexander, B.Sc.(Eng.)
STRICKLAND, William Tolson.
SUTCLIFFE, Trevor Fairbank, M.A
SUTTON, Arthur John, B.Sc.(Eng.).
THRUSH, David John.
TOOMBS, Jack, Capt., R.E.M.E.
TOZER, Basil Laurence, B.Sc.
TUFT, George, B.Sc.
TURNER, James William.
VERNON, James Harold, B.E.
VICKERS, Valentine John, B.Sc. (Eng.).
WADDINGTON, John Charesworth.
WHEELER, Graham Jack Allen, B.Sc.
WILKINSON, Harold George.
WODEHOUSE, Patrick Armine, B.Sc.
WRIGHT, Kenneth James.
ZABOROWSKI, Jozef, Dipl.Ing.

Student to Associate Member

BELLIS, John, B.Sc.
CROSS, Wilfrid, B.Sc.
HILL, Raymond George, B.Sc.(Eng.).

TRANSFERS: 2ND LIST

Associate Member to Member

ABBOTT, Alexander.
CHURCHWARD, Ernest Walker Wallace.
FIELD, James Holden.
GIFFORD, Randolph Douglas, D.Sc.
GRIFFITHS, Trevor, B.Sc.(Eng.).
HAREVEN, David, Capt.
HEMINGWAY, Arthur Victor, B.Sc. (Eng.).
JENKINS, Llewelyn Evans.
KIPPEN, Maxwell Duncan, B.Sc.
LEDSOM, Alexander, M.Eng.
POPPER, Paul, B.Sc.
TODKILL, Herbert.

Graduate to Associate Member

AITKEN, John Alexander, B.Sc.
ALEXANDER, Donald Arthur, M.A.
ALLENDER, James Douglas, B.Eng.
ALTMAN, David.
ANDERSON, James Rodger.
ASHERSON, Jeremy Stanley, B.Sc.Tech.
ATTWOOD, John Antony, B.Sc. (Eng.).
BALLANTYNE, Ernest Harold, B.Sc.
BIRD, Dennis James.
BLOWERS, George Girdley.
BOULTER, Ronald Charles.
BOURNE, Alfred John, B.Sc.
BROWN, Harry Lawrence.
BULLAR, Robert Alan, B.Sc.(Eng.).
CLAYSON, Kenneth Hubert.
COOKE, William.
COOKMAN, John George, B.A.
FENTON, Adrian Walton, B.Eng.
FREESTONE, Roland.
GENT, Geoffrey William.
GILL, Archibald.
GLEDHILL, Geoffrey.
HADEN-SCOTT, Basil Beaumont.
HALLIDAY, Andrew Gilbert, B.Sc. (Eng.).
HARRISON, John Arthur Thomas.
HOLLEYOAK, Vernon Arthur.
JAQUES, Wilfred.
JONES, Neville Eric.
LEACH, Alan Clifford.
MARTIN, John Walker, B.Sc.
MEE, John.
MORLEIGH, Sidney.
MURPHY, Bernard, M.Eng., Ph.D.
NEWEY, Stanley Frederick, B.Sc.
NEWMAN, Wolfgang Simon, B.Sc. (Eng.).
PATTERSON, Peter Donald.
PAUL, Robert John Alexander, B.Sc. (Eng.).
PENMAN, Cyril Leonard.
POPE, Gordon Cecil, B.Eng.
POWELL, Ronald, B.Sc.
QUARMBY, Eric, M.A.
RAWLE, Derwenydd John.
REID, Gerald Wilberforce, B.Sc.(Eng.).
RICHARDSON, Bert.
ROBINSON, Peter Conrad.
ROGERS, Francis John.
ROWLANDS, Thomas John, B.Sc.
SHEARER, James.
SINCLARE, Paul Herbert.
STANDFORD, Richard Thomas Albert, B.Sc.
STENNING, George Peter.
TAYLOR, George William, B.Sc. (Eng.).
THOBURN, Reginald John.
WAHLRAB, Peter Carl, B.E., B.Sc.
WAKELING, Arthur James, B.Sc. (Eng.).
WARREN, Ronald Christopher, B.Sc. (Eng.).
WATT, Dudley Albert, B.Sc.(Eng.).
WEST, Roger, M.A.
WILKES, William John, B.Sc.(Eng.).
WILLIAMS, Keith.
WILLIAMS, William, B.Sc.

Student to Associate Member

BATCHELOR, Michael Wood.

Forthcoming Events at Savoy Place

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E	EDUCATION DISCUSSION CIRCLE	**R**	RADIO AND TELECOMMUNICATION SECTION
I	INFORMAL	**S**	SUPPLY SECTION
M	MEASUREMENT AND CONTROL SECTION	**U**	UTILIZATION SECTION
O	ORDINARY		

After each paper that has now been published is added the month that its synopsis appeared in the *Journal*.

1955

OCTOBER

6 *Thursday* — SIR GEORGE H. NELSON, BART. Inaugural Address as President* — **O**

11 *Tuesday* — W. BAMFORD, B.SC. Chairman's Address* — **M**

13 *Thursday* — D. B. HOGG, M.B.E., T.D. Chairman's Address* — **U**

17 *Monday* — J. H. FRASER, O.B.E., B.SC., will open a discussion on "Railway Signalling"* — **I**

18 *Tuesday* — W. A. TURNER, B.SC.(ENG.), will open a discussion on: "Analogues and Equivalent Circuits"* (at 6 p.m., tea 5.30 p.m.) — **E**

19 *Wednesday* — H. STANESBY. Chairman's Address* — **R**

25 *Tuesday* — D. R. CHICK, M.SC., B.SC., *and* D. P. R. PETRIE, M.SC. — **M**
"An Electrostatic Particle Accelerator" (Paper No. 1869 M)‖ *Synopsis:* July, 1955

S. E. HUNT, PH.D., D. P. R. PETRIE, M.SC., K. FIRTH, B.SC., *and* A. J. TROTT
"An Electrostatic Analyser for the Absolute Measurement of Proton Energies and the Establishment of Fixed Points on the High-Voltage Scale" (Paper No. 1840 M)‖ *Synopsis:* June, 1955.

26 *Wednesday* — L. DRUCQUER. Chairman's Address* — **S**

31 *Monday* — *At 2.30 p.m.*
E. D. R. SHEARMAN, B.SC.(ENG.) — **R**
"The Technique of Ionospheric Investigation using Ground Back-Scatter" (Paper No. 1915 R)§
and
"A Study of Ionospheric Propagation by means of Ground Back-Scatter" (Paper No. 1914 R)§

R. W. MEADOWS, B.SC.(ENG.)
"An Experiment to Test the Reciprocal Radio Transmission Conditions over an Ionospheric Path of 740 km" (Paper No. 1901 R)‖ *Synopsis:* See page 608

F. J. M. LAVER, B.SC., *and* H. STANESBY
"An Experimental Test of Reciprocal Transmission over Two Long-Distance High-Frequency Radio Circuits" (Paper No. 1904 R)§

At 5.30 p.m.
W. J. BRAY, M.SC.(ENG.), J. A. SAXTON, D.SC., PH.D., R. W. WHITE, B.SC., *and* G. W. LUSCOMBE, B.SC.(ENG.)
"V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication" (Paper No. 1920 R)§

District Meetings

Arrangements for October and November for District meetings other than those held in the area of a Local Centre.

OXFORD (At the Southern Electricity Board, 37 George Street, at 7 p.m.)

OCTOBER **12** *Wednesday* — H. PAGE, M.SC. "The New High-Quality F.M. Broadcasting Network"*

NOVEMBER **9** *Wednesday* — R. H. GOLDE, PH.D. "Lightning Surges on Electrical Supply Systems"*

* No advance information will be available. § This paper will be published not later than 10 days before the date of reading.
‖ This paper has now been published separately (see page 607).

Contents of the Current Issues of the Proceedings

DATE OF JOURNAL DIGEST OR SPECIAL ARTICLE

PART A. POWER ENGINEERING (AUGUST 1955)

See August *Journal* page 549.

PART B. RADIO AND ELECTRONIC ENGINEERING (SEPTEMBER 1955)

September 1955
JOHN C. WEST, B.SC., PH.D., AND JOHN L. DOUCE, M.SC.
The Mechanism of Sub-Harmonic Generation in a Feedback System (PAPER NO. 1693 M, JULY 1954)

Digest not yet published
JOHN C. WEST, B.SC., PH.D., AND P. N. NIKIFORUK, B.SC.
The Response of Remote-Position-Control Systems with Hard-Spring Non-Linear Characteristics to Step-Function and Random Inputs (PAPER NO. 1728 M, OCTOBER 1954)

Digest not yet published
A. T. FULLER, M.A.
The Adjustment of Control Systems for Quick Transient Response (PAPER NO. 1878 M)

Digest not yet published
H. H. ROSENBROCK, B.SC.(ENG.), PH.D.
The Integral-of-Error-Squared Criterion for Servo Mechanisms (PAPER NO. 1865 M)

Discussion on **The Manchester–Kirk o'Shotts Television Radio-Relay System** before the Western Centre and the Southern Centre

June 1955
D. M. MACKAY, B.SC., PH.D.
High-Speed Electronic-Analogue Computing Techniques (PAPER NO. 1738 M, OCTOBER 1954)

June 1955
P. E. AXON, O.B.E., M.SC., PH.D., C. L. S. GILFORD, M.SC., AND D. E. L. SHORTER, B.SC.(ENG.)
Artificial Reverberation (PAPER NO. 1796 R, FEBRUARY 1955)

September 1955
A. STOTT, M.A., AND P. E. AXON, O.B.E., PH.D., M.SC.
The Subjective Discrimination of Pitch and Amplitude Fluctuations in Recording Systems (PAPER NO. 1874 R)

Special article not yet published
G. H. METSON, M.C., PH.D., M.SC., B.SC.(ENG.)
A Study of the Long-Term Emission Behaviour of an Oxide-Cathode Valve (PAPER NO. 1790 R, APRIL 1955)

Digest not yet published
G. H. METSON, M.C., PH.D., M.SC., B.SC.(ENG.), E. F. RICKARD, B.SC., AND F. M. HEWLETT, B.SC.
Some Experiments on the Breakdown of Heater-Cathode Insulation in Oxide-Cathode Receiving Valves (PAPER NO. 1857 R)

Written discussion on **Noise Generation in Crystals and Ceramic Forms of Barium Titanate when subjected to Electric Stress**

Digest not yet published
A. C. GORDON-SMITH
A Milliwattmeter for Centimetre Wavelengths (PAPER NO. 1888 R)

Digest not yet published
G. J. PHILLIPS, M.A., PH.D., B.SC.
V.H.F. Aerials for Television Broadcasting (PAPER NO. 1890 R)

Digest not yet published
D. G. SARMA, M.SC.
On Distributed Amplification (PAPER NO. 1889 R)

Digest not yet published
A. E. KARBOWIAK, PH.D.
Theory of Imperfect Waveguides: The Effect of Wall Impedance (PAPER NO. 1841 R)

Written discussion on **A General Experimental Method to Determine the Properties of Artificial Media at Centimetre Wavelengths, applied to an Array of Parallel Metallic Plates**

Digest not yet published
N. P. ROBINSON, M.A.
Measurements of the Effect of Rain, Snow and Fogs on 8·6 mm Radar Echoes (PAPER NO. 1898 R)

Discussion on **Submerged Telephone Repeaters for Shallow Water** and **The British Post Office Standard Submerged-Repeater System for Shallow-Water Cables, with special mention of the England–Netherlands System** before the North-Eastern Radio and Measurements Group and the South-Western Sub-Centre

Discussion on **A Short Modern Review of Fundamental Electromagnetic Theory** before the Mersey and North Wales Centre and the North-Eastern Radio and Measurements Group

Discussion on **A Transatlantic Telephone Cable** before the North-Western Centre

Digest of a paper:

A. HOBSON, M.SC.TECH. **Current Summations with Current Transformers** (PAPER NO. 1678 M, JUNE 1954)

Digests of Institution Monographs:

P. E. W. GRENSTED, M.A. **The Frequency-Response Analysis of Non-Linear Systems** (MONOGRAPH NO. 126 M, APRIL 1955)

PATRICK T. G. FLYNN, B.SC.(ENG.), PH.D. **Field-Dependent Conductivity in Non-Uniform Fields and its Relation to Electrical Breakdown** (MONOGRAPH NO. 128 M, APRIL 1955)

J. H. MASON, B.SC. **Breakdown of Solid Dielectrics in Divergent Fields** (MONOGRAPH NO. 127 M, APRIL 1955)

W. S. PERCIVAL, B.SC. **The Graphs of Active Networks** (MONOGRAPH NO. 129 R, APRIL 1954)

PROFESSOR N. F. ASTBURY, M.A., SC.D. **Residual Effects in the Campbell Bridge Method for the Absolute Measurement of Resistance, and a Note on a New Bridge** (MONOGRAPH NO. 130 M, APRIL 1955)

I. A. HARRIS **The Theory and Design of Coaxial Resistor Mounts for the Frequency of Band 0–4000 Mc/s** (MONOGRAPH NO. 132 R, MAY 1955)

S. DEMCZYNSKI, DIPL.ENG. **The Correlation between Decay Time and Amplitude Response** (MONOGRAPH NO. 139 R, JULY 1955)

Contents of the Current Issues of the Proceedings *(contd.)*

PART C. MONOGRAPHS (SEPTEMBER 1955)

(Digests of monographs are not published in the Journal)

J. W. LYNN, M.SC.
The Tensor Equations of Electrical Machines (No. 117 S, JANUARY 1955)

A. TALBOT, M.A., PH.D.
Some Fundamental Properties of Networks without Mutual Inductance (No. 118 R, JANUARY 1955)

H. V. SHURMER, M.SC., PH.D.
A Direct-Reading Waveguide Standing-Wave Detector for Use at Low Power Levels (No. 119 R, JANUARY 1955)

D. G. TUCKER, D.SC., PH.D.
Signal/Noise Performance of Multiplier (or Correlation) and Addition (or Integrating) Types of Detector (No. 120 R, FEBRUARY 1955)

D. MCDONNELL AND W. R. PERKINS, B.SC.
The Stability and Time Response of Fast-Operating Closed-Loop Pulsed Radar Circuits (No. 121 R, MARCH 1955)

K. W. H. FOULDS, PH.D., B.SC.(ENG.)
Resonant-Cavity Measurements of the Relative Permittivity of a D.C. Discharge (No. 122 M, MARCH 1955)

PROFESSOR G. W. CARTER, M.A.
A Note on the Surface Loss in a Laminated Pole-Face (No. 123, MARCH 1955)

R. F. SAXE, PH.D., AND PROFESSOR J. M. MEEK, D.ENG.
The Initiation Mechanism of Long Sparks in Point-Plane Gaps (No. 124 M, APRIL 1955)

W. E. LEWIS, PH.D., AND J. H. BANKS, B.SC.
Matrix Methods for the Evaluation of Simultaneous Faults in Three-Phase Systems (No. 125 S, APRIL 1955)

P. E. W. GRENSTED, M.A.
The Frequency-Response Analysis on Non-Linear Systems (No. 126 M, APRIL 1955)

J. H. MASON, B.SC.
Breakdown of Solid Dielectrics in Divergent Fields (No. 127 M, APRIL 1955)

PATRICK T. G. FLYNN, B.SC.(ENG.), PH.D.
Field-Dependent Conductivity in Non-Uniform Fields and its Relation to Electrical Breakdown (No. 128 M, APRIL 1955)

W. S. PERCIVAL, B.SC.
The Graphs of Active Networks (No. 129 R, APRIL 1955)

PROFESSOR N. F. ASTBURY, M.A., SC.D.
Residual Effects in the Campbell Bridge Method for the Absolute Measurement of Resistance, and a Note on a New Bridge (No. 130 M, APRIL 1955)

ERICH UHLMANN, DR.ING.
Alternating Voltage, Direct-Voltage Regulation and Power Factor of Convertor Stations operating on A.C. Systems of Finite Short-Circuit Capacity (No. 131 S, MAY 1955)

Note on **Synthesis of Ladder Networks to give Butterworth or Chebyshev Response in the Pass Band**

Addendum to **The Pulse Transfer Function and its Application to Sampling Servo Systems**

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